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Programmable hand-held calculators in the operating forces of the Marine Corps

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Monterey, California

THESIS

Programmable Hand-Held Calculators
in the Operating Forces of
the Marine Corps

by

James LeBaron Reeve

March 1981

Thesis Advisor: W. H. Skierkowski

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Programmable Hand-Held Calculators in the Operating Forces of the Marine Corps

by

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Major, United States Marine Corps
B.S., Iowa State University, 1969

Submitted in partial fulfillment of the requirements for the degree of

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March 1981

ABSTRACT

This thesis provides usage and cost data on programmable hand-held calculators (PHHC's) in the operating forces of the U. S. Marine Corps (USMC). In 1978 PHHC's that computerized aircraft performance charts were procured for USMC AV-8A pilots. During 1979 the U. S. Army successfully tested and began procuring a PHHC for use by artillery fire direction centers (FDC's). USMC artillery batteries will receive this PHHC in 1981. In 1980 the Army tested and approved procurement of PHHC's for mortar FDC's. In September 1980 Beech Aircraft Corporation started selling a PHHC module which enabled Super King Air pilots to enjoy 10% fuel savings. In February 1981 Naval Air Systems Command began reviewing a proposal to provide a PHHC for the CH-53E. Each of these systems is described, and available cost information is analyzed. In order to do their jobs faster and more accurately, several individuals have written or purchased software for their personal PHHC's. Four examples which have application in the USMC are presented and explained.

TABLE OF CONTENTS

I. INTRODUCTION

A. GENERAL INFORMATION

The evolution of the computer, and in particular the recent developments in programmable hand-held calculators, has not gone unnoticed by the military services. Many base facilities are taking advantage of the new minicomputers, microcomputers, and word processing equipment on the market today. The operating forces can foresee a need for rapid information processing and electronic decision support systems; however, it must be portable, light weight, low cost, and not easily affected by the elements.

In 1974 Hewlett-Packard (HP) introduced their HP-65, which was the first card programmable hand-held calculator. Until Texas Instruments (TI) began marketing their SR-52 in January of 1976, the HP-65 was without competition. The HP-67 introduced by Hewlett-Packard in June of 1976 had twice the capability of the HP-65. Texas Instruments replaced their SR-52 with a much improved TI-59 in June of 1977. [Ref. 1: pp. 9-10]

The TI-59 was a state-of-the-art improvement in that it was not only card programmable but also "chip programmable". The terms "chip programmable" and "module programmable" are sometimes used interchangeably. In reality, a chip is a tiny piece of silicon, and a module is the molded plastic

housing containing the chip and the copper connectors through which the chip "communicates" with the calculator's operating system. A Texas Instruments module measures 11/16 by 7/8 by 5/16 inch. It is inserted in a special opening in the back of a TI-59. Program instructions can be recorded on, or deleted from, magnetic cards by using the card reader/card writer. Chips can only be encoded by a complex industrial process. One advantage of chip programming is that more information can be stored on one Texas Instruments chip than on ten of their magnetic cards. Since the TI-59's random access memory can only store, at any one time, the information on two magnetic cards, TI's chip programming increased by five fold the amount of information immediately available for automated processing by the calculator. This feature was not answered competitively until May of 1980 with the advent of the HP-41C. As might be expected, the HP-41C is another step forward. It has more storage, constant memory, and improved alphanumeric capability.

The TI-58 was introduced by Texas Instruments at the same time as the TI-59. The TI-58 is chip programmable by the same module as is the TI-59; however, the TI-58 does not have a card reader and has only about half the storage of the TI-59. Both have the same face plate and are identical in size. A constant memory version of the TI-58 is now offered and is called the TI-58C. Texas Instruments has not, as yet, marketed a constant memory TI-59.

During January of 1981 the TI-58C could be purchased for $89.95, the TI-59 for $199.95, the HP-67 for $299.95, and the HP-41C for $189.95. To be card programmable the HP-41C requires an attachable card reader which costs $169.95. In addition, the HP-41C can be programmed with an optical wand which reads bar code from standard paper. The optical wand is available for $109.95. Hewlett-Packard also markets the HP-41CV which is an HP-41C with additional built-in memory modules. The HP-41CV costs $239.95. For a package price of $394.95 you can purchase an HP-41CV and the plug-in card reader. [Ref. 2]

Thermal printers are available for the TI-58/TI-59 series programmable hand-held calculators (PHHC's). Likewise, Hewlett-Packard has a thermal printer for its HP-41C/HP-41CV PHHC. The Texas Instruments printer costs $159.95, while $289.95 will buy Hewlett-Packard's printer. The prices for these printers and the prices for the PHHC's in the preceding paragraph were advertised nationally by a discount firm selling manufacturer-warranted equipment. [Ref. 2]

During the period 15 August to 30 September of 1977 the U. S. Army Field Artillery School (USAFAS) conducted an evaluation of the feasibility of using card programmable hand-held calculators to derive aiming solutions for artillery cannons. This concept evaluation test was the forerunner of what is now formal usage of PHHC's by U. S. Army and

U. S. Marine Corps artillery units. This is discussed in more detail in Chapter II.

The card programmable calculator was not considered to be acceptable for formal usage as an aircraft flight planning aid; however, the U. S. Marines were the first to identify and incorporate the chip programmable TI-58 as a means of computerizing aircraft performance data and mission planning tasks. Chapter II provides an in-depth analysis of this concept.

B. SCOPE

This thesis will consolidate the body of information pertaining to PHHC usage in the operating forces of the U. S. Marine Corps (USMC). Accordingly, the scope of this study does not include PHHC usage at Headquarters Marine Corps (HQMC) or in the Marine Corps Districts. Usage in the Marine Corps Reserve is applicable.

The thesis will analyze the programs currently being used and will report on the programs currently being considered or under development.

C. DEFINITIONS

The term "formal program" is defined by this thesis to be usage which is developed and funded by the government.

An "informal program" is defined to be usage which is conceived, implemented, and funded by an individual serving with the operating forces.

D. PURPOSE OF THE THESIS

In addition to consolidating the body of information pertaining to PHHC's in the USMC, this thesis will investigate the way in which the software for the formal programs was produced. The information consolidation is contained in Chapters II and III.

The U. S. Army used in-house programmers, both civilians and military, to write the software for the artillery applications. After the software was written, verified, and emulated, the Army dealt directly with Texas Instruments for production and purchase of the customized modules, or the read only memories (ROM's) as the modules are sometimes called.

By contrast, the PHHC's now used in Marine Corps AV-8A squadrons were procured via a firm fixed price contract between Naval Air Systems Command and McDonald Douglas Aircraft Corporation.

In Chapter IV the cost of obtaining software by the in-house method is compared to the cost of obtaining it via an outside contractor.

The diversity and extent of informal program usage are limited only by the ingenuity of the individuals owning or having access to PHHC's. Four different examples of informal programs are cited in Chapter V. A program listing and instructions for running each program are included in the appendixes.

E. RESEARCH METHODOLOGY

Assisted by computer-generated searches, a review of the pertinent literature was conducted. Since this is a highly contemporary subject, much of the information has not yet been published. Accordingly, the research for this thesis included numerous telephone interviews.

Telephone calls were made to the Naval Air Training and Operating Procedures Standardization (NATOPS) Officer at HQMC, the NATOPS Officer in each of the four Marine Aircraft Wings, the Naval Air Systems Command Class Desk Office for each type aircraft in the Marine Corps inventory, a McDonald Douglas engineer, a McDonald Douglas technical publications supervisor, a Beech Aircraft customer service official, a new business representative at Texas Instruments, a Hewlett-Packard customer service official, a Hewlett-Packard custom ROM (read only memory) district manager, a Warrant Officer in the firepower branch at the Marine Corps Development Center at Quantico, Virginia, a Marine First Lieutenant instructing at the U. S. Army Field Artillery School at Fort Sill, Oklahoma, several artillery officers at Camp Lejeune, North Carolina, the test officer for the Army's PHHC Mortar Data Module Firing Program Evalution, several programmers who worked on the artillery PHHC modules, three former thesis authors whose subject pertained to PHHC's, and numerous other individuals known by this author to have special interest in programmable hand-held calculators.

Personal interviews were conducted with two officers at the Naval Aviation Safety School at the Naval Postgraduate School in Monterey, California and with an officer in the 7th Division Artillery Headquarters at Fort Ord, California.

Each of the contacts mentioned in the above two paragraphs provided information, generally in the form of letters or publications, but sometimes just verbally. In addition, the four Marine Aircraft Wing NATOPS Officers each completed and returned a questionaire soliciting their opinions on PHHC usage by aircrews.

II. EXISTING FORMAL PROGRAMS

A. AVIATION APPLICATION

1. Background Information

In order to fly an aircraft near the edge of its safe operating envelope it is necessary to know the performance limits for the configuration and situation in which the aircraft is going to be flown. Those limitations can change drastically with temperature, altitude, wind, aircraft weight, and aircraft drag index. For example, an A-6 aircraft may require as little as 800 or as much as 8500 feet of runway to become airborne. On a day at 60 degrees Fahrenheit temperature at sea level an A-6 aircraft in a certain configuration will use 4500 feet of runway before it will fly. The same aircraft on a 90-degree day at 4000 feet above sea level will never become airborne regardless of the length of the runway. Another example involves the differing amounts of fuel required to fly a certain distance as the mission changes. The A-6 may require as little as one gallon per nautical mile, or as much as five, depending on the number of bombs carried, the speed, and the altitude at which the mission is flown.

Making the right decision regarding whether it is safe to fly in a certain configuration in a specific situation necessitates a decision support system (DSS). The

following sections will describe the current DSS, its problems, and how programmable hand-held calculators (PHHC's) can create a new DSS. The obstacles to incorporating PHHC's as flight planning DSS's for additional aircraft will be discussed in Chapter IV. Recommendations on how the obstacles might be overcome will be offered in Chapter VI.

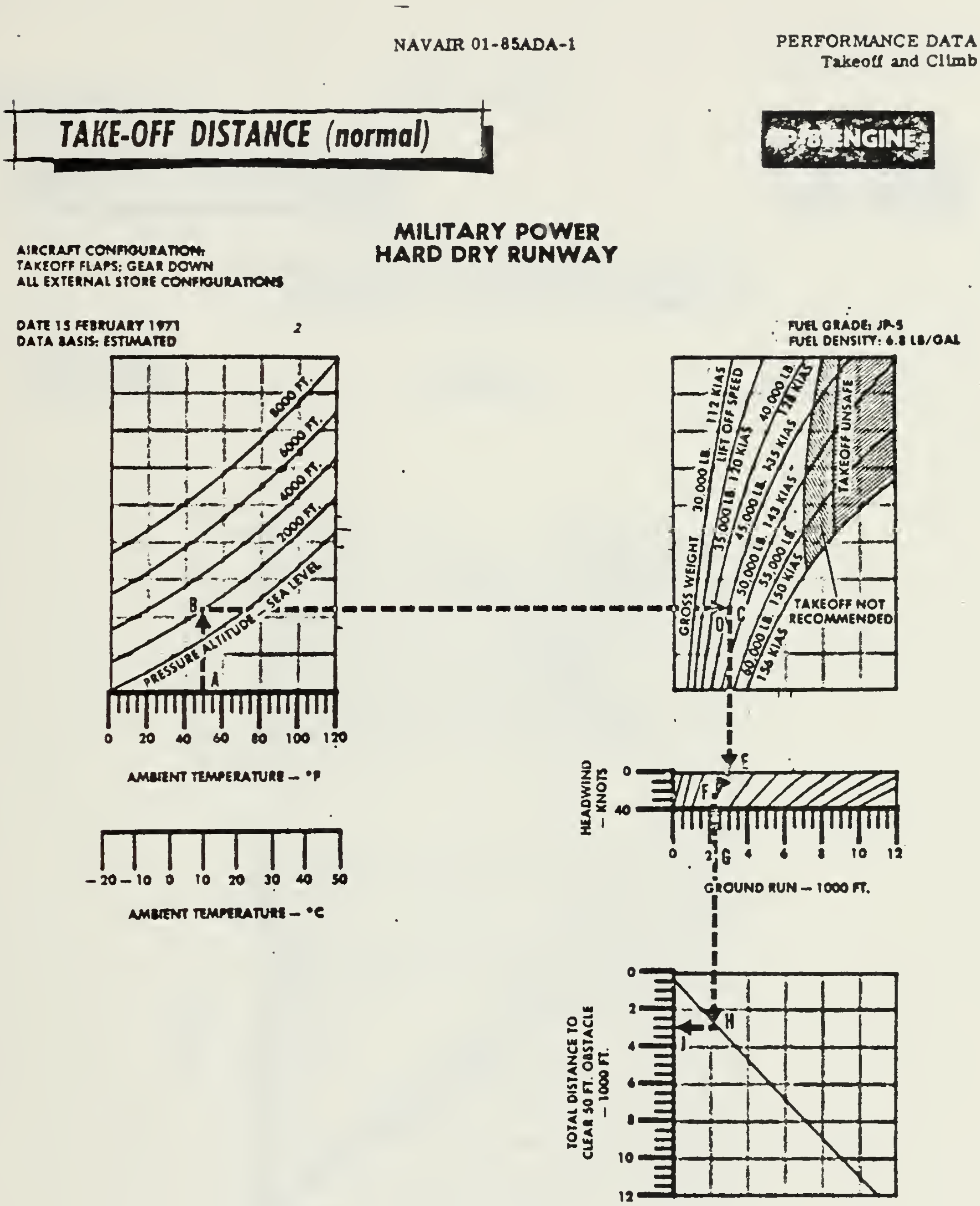
2. The Current Decision Support System

Each aircraft type has a different Naval Air Training and Operating Procedures Standardization (NATOPS) flight manual. Section XI of this manual contains a performance data section. In the A-6 aircraft NATOPS manual, Section XI's 182 pages include 150 different figures and the instructions for using them. Figure II-1, Figure II-2, Figure II-3, and Figure II-4 are reduced-in-size copies of four of those 150 figures. Figure II-1 is used to determine the takeoff distance under all possible circumstances. Figures II-2, II-3, and II-4 are used to determine the time required, fuel required, and distance required to descend to sea level from a specific altitude. These are only four of many types of computations which must be considered in rendering effective and efficient decisions regarding flight missions.

3. Problems With the Current System

Using NATOPS flight performance charts and graphs is so time consuming and tedious that many Naval Aviators and Naval Flight Officers avoid using the NATOPS manual when

Figure II-1



Source: A-6 NATOPS Flight Manual, page 11-19

Figure II-2

PERFORMANCE DATA
Drag Count

NAVAIR 01-85ADA-1

MAXIMUM RANGE DESCENT

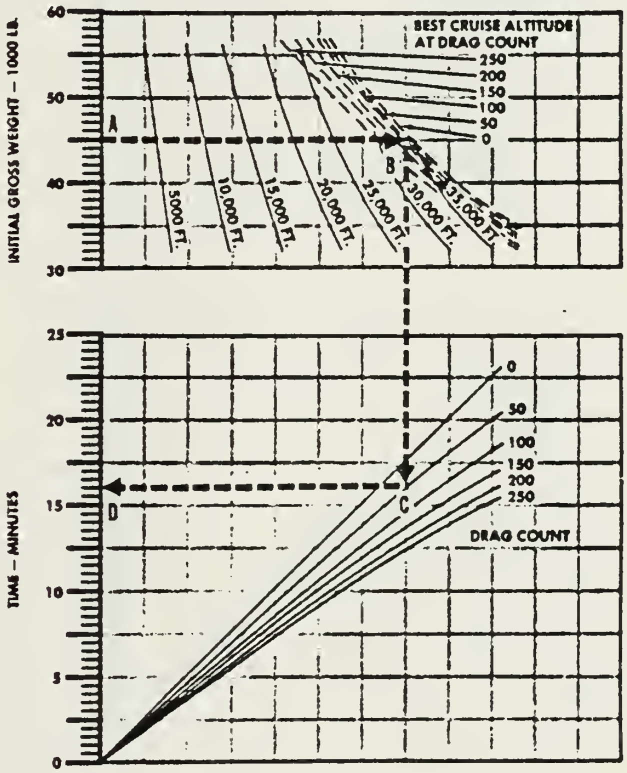
P-8 ENGINE

TIME REQUIRED TO DESCEND FROM SELECTED ALTITUDE TO SEA LEVEL IDLE POWER

DATE 15 MARCH 1971
DATA BASIS: ESTIMATED

REMARKS
ICAO STANDARD DAY

FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LB./GAL.



Source: A-6 NATOPS Flight Manual, page 11-162

Figure II-3

NAVAIR 01-85ADA-1

PERFORMANCE DATA
Drag Count

MAXIMUM RANGE DESCENT

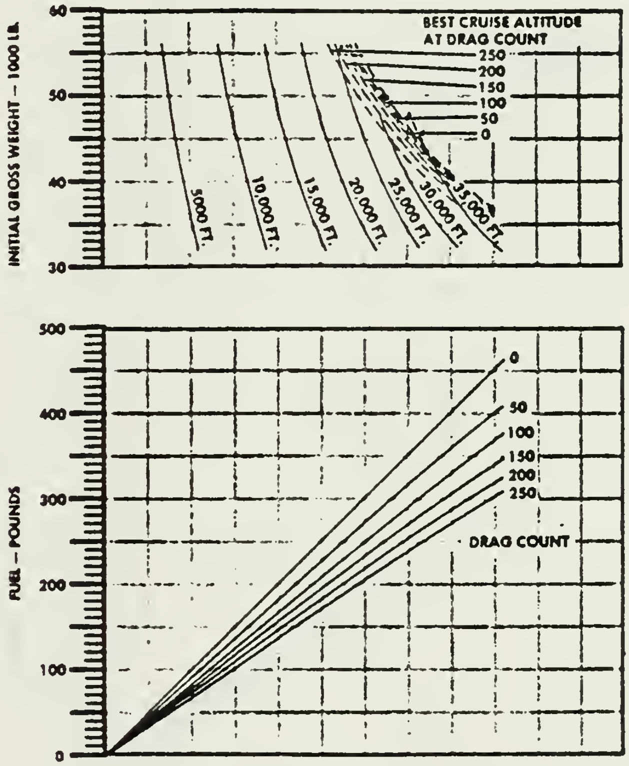
ENGINE

FUEL REQUIRED TO DESCEND FROM SELECTED ALTITUDE TO SEA LEVEL IDLE POWER

DATE 15 MARCH 1971
DATA BASIS: ESTIMATED

REMARKS
ICAO STANDARD DAY

FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LB./GAL.



Source: A-6 NATOPS Flight Manual, page 11-163

Figure II-4

PERFORMANCE DATA
Drag Count

NAVAIR 01-85ADA-1

MAXIMUM RANGE DESCENT

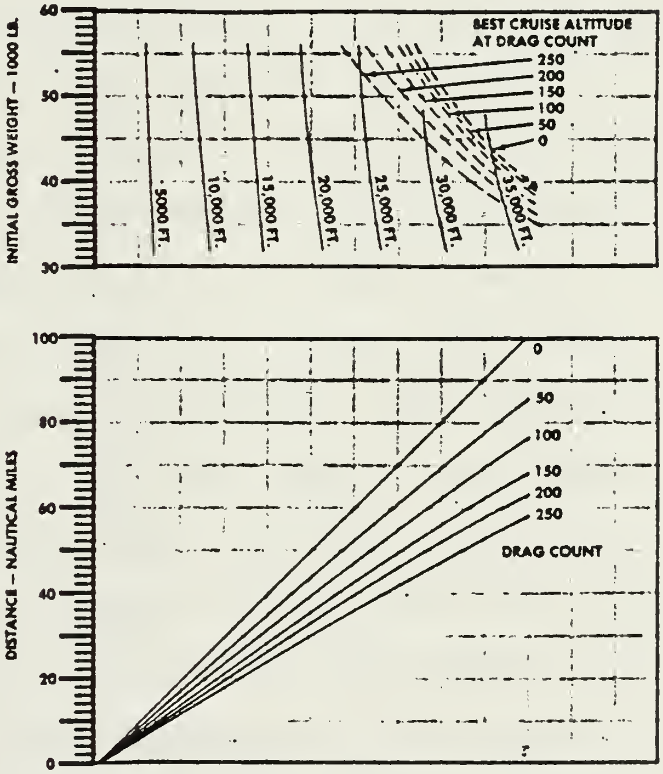
P-8 ENGINES

DISTANCE REQUIRED TO DESCEND FROM SELECTED ALTITUDE TO SEA LEVEL IDLE POWER

DATE 15 MARCH 1971
DATA BASIS: ESTIMATED

REMARKS
ICAO STANDARD DAY

FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LB./GAL.



Source: A-6 NATOPS Flight Manual, page 11-164

doing their flight planning. Instead they substitute figures learned from experience or obtained from "rough gouge" cards they or someone else prepared for a stereotyped situation. This is not a problem if the flight mission does not involve operation at or near the edge of the envelope. It can become a problem, with disastrous consequences, if any one of several parameters is violated.

If inadequate aircrew planning occurs in the following examples, loss of lives and equipment will most probably result. Increased temperature, increased elevation, and decreased headwind component all cause a greater takeoff distance in order for an aircraft at a specified weight to become airborne. Attempting to takeoff with insufficient runway length for the specific aircraft weight, or runway temperature, or runway elevation, or headwind component will result in a crash every time. It is also true that altitude, temperature, wind speed, wind direction, aircraft speed, aircraft weight, and ordnance drag index have known effects upon the fuel required per mile flown. The result of running out of fuel while airborne can be predicted without reference to any NATOPS chart.

Lieutenant Commander W. M. Siegel, an aeronautics student at the Naval Postgraduate School in Monterey, California, quoted an interview with the former Director of the Naval Aviation Safety School in regard to a one-hour test which was administered to sixteen officers attending

the Command Safety Course. This course is for commanding officers and executive officers. The test required that these pilots and naval flight officers compute the maximum range at which a specified mission could be flown. The director stated:

> "It is a startling, but typical, fact that the correct answer of 538 nautical miles was not achieved by any member of the class. The closest answer was in error by 126 miles, and the spread of answers ranged from 336 to 868 nautical miles. Additionally, the correct answer was attained by the class instructor only after a measured sixteen hours of effort with the NATOPS manual." [Ref. 3: p. 10]

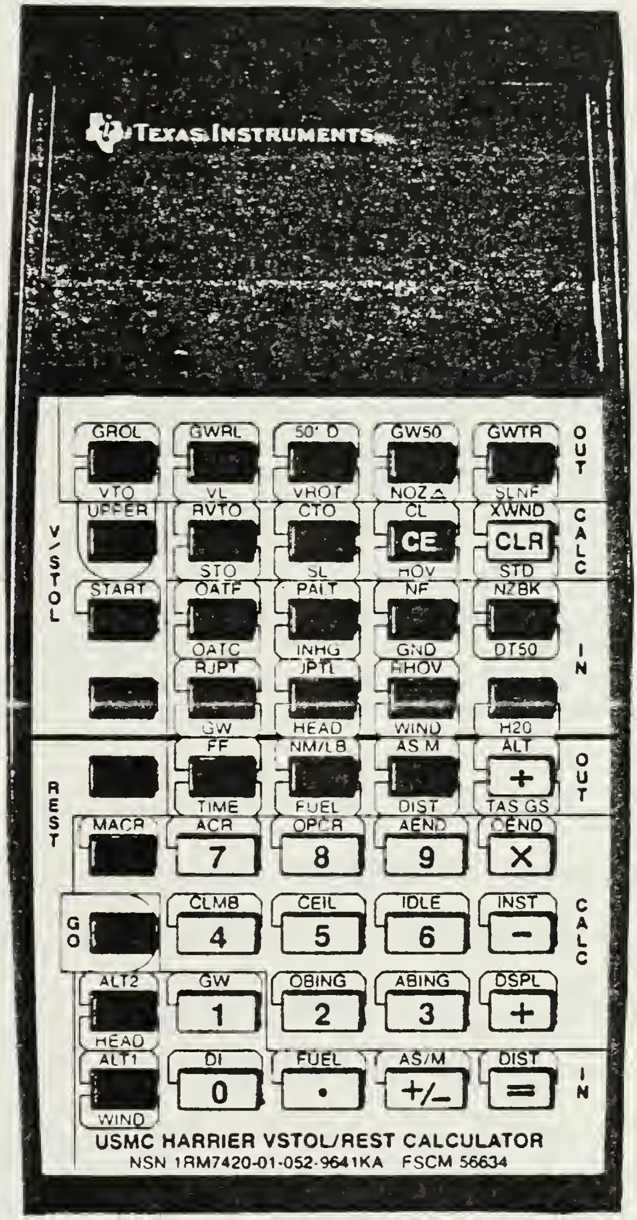
4. An Improved Decision Support System

In 1978 another Naval Postgraduate School aeronautics student, Lieutenant Commander G. L. Koger, demonstrated that a programmable hand-held calculator (PHHC), the Texas Instruments Model 59 (TI-59), could be card programmed to compute data which previously had to be derived from NATOPS manual performance charts. [Ref. 4: pp. 90-138]

Even before Major J. D. Restivo [Ref. 5], Seigel [Ref. 3], and Koger [Ref. 4] had presented their theses demonstating that NATOPS performance charts and graphs could be computerized, U. S. Marine Corps AV-8A Harrier pilots had recognized the need for a better DSS. In August 1977 Naval Air Systems Command contracted with McDonald Douglas Aircraft Corporation "for development of an electronic hand-held calculator and delivery of 200 units." [Ref. 6] These calculators were delivered in June 1978; their usage was

Figure II-5

The AV-8A/TAV-8A V/STOL-REST Flight Performance Calculator



Note: The above picture is the same size as the actual calculator.

implemented immediately by Marine Corps AV-8A Harrier squadrons at Cherry Point, North Carolina. The Harrier calculator is a Texas Instruments Model 58 (TI-58) with a modified face plate and a customized module. Figure II-5 is a picture of the Harrier calculator. The foreword to its operating instructions is reproduced, in part, below.

> "The AV-8A/TAV-8A V/STOL-REST Calculator has been designed to calculate the performance of AV-8A and TAV-8A aircraft easily. In essence, the entire Performance Data Section of the NATOPS Flight Manual has been incorporated into the calculator. The fit of the performance data for the Calculator has been done mathematically, while the fit for the NATOPS Manual was done graphically. This introduces some differences in specific performance points in certain cases, but these differences are small.
>
> The Calculator can be used for calculating all Vertical or Short Takeoff and Landing (V/STOL) and wingborne Range, Endurance, Speed, and Time (REST) maneuvers. The characteristics of an individual aircraft can be entered to provide the aircraft's maximum capabilities to the pilot. The possibility of error is greatly reduced when using the Calculator as opposed to the "reflector" and "chase-around" charts in the NATOPS Manual." [Ref. 7: p. 2]

Although there have been no formal studies conducted regarding the time savings enjoyed by users of this calculator, interviews with Harrier pilots indicate at least a 25% savings. No pilot interviewed said it required more than ten hours to become proficient in using the calculator, and one pilot reported 95% proficiency after only 1.5 hours of instruction and practice. The accuracy of the calculator-generated data is nearly 99% perfect, which is considerably more accurate than using the NATOPS charts and graphs where the width of a pencil line drawn on a most of the graphs

will limit accuracy to 95%. Accuracy can also be degraded in the manual mode if transfers between graphs on the same figure are not exactly parallel to the axes of the graphs.

In order to facilitate in-cockpit use of the calculator, a special strap was designed and procured which enables the pilot to strap the calculator to his leg in a manner similar to that done with the conventional aviator's kneeboard. For a variety of reasons, most of which are related to either the small size of the AV-8A cockpit or the high workload rate, a majority of the pilots found it was not practical to use the calculator during flight. Accordingly, the requirement for a strap was deleted from the contract specification of the planned-for AV-8C calculator, which will be discussed in more detail in Chapter IV.

B. ARTILLERY APPLICATION

1. History of PHHC Adoption and Implementation

a. Card Programmed Phase

During the period from 15 August to 30 September of 1977 a Concept Evaluation Test was conducted at the U. S. Army Field Artillery School (USAFAS), Fort Sill, Oklahoma. This test employed the TI-59 in its card programmable mode to solve gunnery problems. Due to the encouraging results of this test, the USAFAS initiated plans to develop the PHHC as a "universal tool to be used for sound and flash, cannon/lance gunnery, and survey procedures." [Ref. 8]

Although the Army published the TI-59 program listings and program operating instructions, the information was not to be construed as official doctrine concerning the solution of artillery gunnery problems. In addition, the Army published the flow charts and equations used to write the TI-59 program. This was to "allow programming of any other calculator with the same features and capabilities as the TI-59." [Ref. 8] Another PHHC with similar card programmability was the HP-67.

Due to the fragile nature of magnetic cards, the unpredictable reliability of the card reader in cold, wet, or dusty weather, and the inherent storage limitation of magnetic cards, the card programmed hand-held calculator was never adopted for doctrinal artillery use.

A card programmed TI-59 can store up to 960 program steps if no data registers are needed. For each ten data registers added by repartitioning, eighty program steps are not available. By contrast, a chip or module (the technical term is ROM for "read only memory") programmed TI-59 has 5000 program steps and 100 data registers available. In addition, the module is much less affected by weather than are the magnetic cards and the card reader.

b. Module Programmed Phase

To overcome the disadvantages of card programming and to exploit the advantages of module programming, the USAFAS developed and tested a prototype module. This

test was conducted during the period 12 December 1978 to 11 May 1979. One objective of the test was to compare the operational capability of the PHHC with FADAC (Field Artillery Digital Automatic Computer) in regard to the solution to indirect fire gunnery. One major assessment of this test was that the PHHC "can function as a backup or alternate for FADAC." [Ref. 9: p. 1-6] That assessment was based on the finding that "there was no statistically significant difference between the two systems" [Ref. 9: p. 2-9] in regard to (1) the accuracy of computed firing data and (2) the time needed to compute the data. The success of this testing and the Material Readiness Command's inability to logistically support FADAC in the 1980's led the Army to develop and procure nine different customized modules. Five of the modules are for five different cannons. The other four modules are used in ancillary artillery support roles. The January-February 1980 issue of Field Artillery Journal [Ref. 10] contains an excellent article which explains the features and capabilities of this new doctrinal application of the TI-59 to the needs of the field artillery. Army units have already received their "Computer Sets", as the Army has chosen to call this new usage of the PHHC. Marine Corps units will receive theirs during 1981.

A "Computer Set, Field Artillery, General" contains a TI-59 (with no module), applicable technical instruction manuals, and external power source connectors so

that the TI-59 can receive electrical power from any of the following four sources in addition to its own organic rechargeable battery pack: (1) a jeep battery, (2) a standard vehicle cigar lighter outlet, (3) an AN/PRC-77 radio battery (BA 4386), or (4) a 115V 60 Hz outlet. All the above, plus the Texas Instruments printer for the TI-59, are included in the "Computer Set, Field Artillery, Missile", which is issued only to the survey information centers in the various headquarters. Any of the nine developed modules needed for the unit's mission are ordered separately.

2. Comments from a Marine Artillery Officer

In order to keep abreast of the evolving PHHC technology and its application to artillery, Marine First Lieutenant Edward A. Bream purchased a TI-59 and its associated printer during May of 1979. Using the TI-59 cannon program information in Reference 8, Bream was able, in his capacity as a battery fire direction officer, to perform a personal feasibility evaluation of that program. In a letter solicited by this thesis author, Bream wrote that one of the advantages of the TI-59 over the manual methods is the precision in which data is determined. Bream succinctly stated that:

> "Manual methods of determining target location involve the relative placement of pins on a firing chart, coupled with a variety of tools designed to numerically categorize the pins' relationship to the chart and to each other. Imbued in this method, however, is the recognized error generated by the manual nature of the system itself. Although two charts are used as a countercheck for errors

against each other, comparative errors of thirty meters in range and three mils in deflection are acceptable. Error skews that develop simultaneously on both charts are almost totally undetectable. Generation of data by the TI-59 is developed along constant mathematical relationships which results in extremely accuate and refined computations."

The disadvantages Bream pointed out dealt with (1) the nature of card programming and (2) the power-source problems. These disadvantages are overcome by module programming and by adaptions for alternate sources of power as explained earlier.

III. FORMAL PROGRAMS UNDER DEVELOPMENT

A. AVIATION APPLICATION

1. The Marine Corps/Navy CH-53E Heavy Lift Helicopter

Naval regulation requires that certain categories of transport aircraft be provided with a system for calculating center of gravity under all possible load conditions. In the past this has been accomplished by procuring, at considerable cost, a specially designed slide rule. In May of 1980 Naval Air Systems Command requested that Sikorsky Aircraft submit an engineering change proposal to the CH-53E procurement contract which would substitute a PHHC for the center-of-gravity slide rule. The request stated, "Electronic calculators are available for approximately the same price as the MIL-C-6092A balance computer." [Ref. 11] A CH-53E calculator similar in function to the AV-8A calculator would be able to do certain performance calculations in addition to the center-of-gravity computations because the latter would only use a portion of the 5000 steps available in a TI-58 module.

The Sikorsky proposal probably would have been quickly submitted except for one development. That development was Hewlett-Packard's newest PHHC, the HP-41C. Its enhanced alphanumeric capability, increased storage capacity, and constant memory caused Sikorsky and Naval Air Systems

Command to agree that Sikorsky should take the additional time necessary to evaluate this new PHHC and how it could be employed in a flight planning decision support system role for the CH-53E. Accordingly, Naval Air Systems Command now expects Sikorsky will, during February of 1981, submit two proposals: one for using a TI-58 and one for using an HP-41C. Naval Air Systems Commmand will evaluate both proposals and will select the one with the higher benefit-to-cost ratio.

2. <u>The Beechcraft Flight Planning Computer</u>

Sikorsky's research and Naval Air Systems Command's analysis will both be made much easier and more accurate thanks to a Beech Aircraft Corporation innovation, an innovation which is truly a state-of-the-art breakthrough for flight planners. During September of 1980 Beech Aircraft Corporation introduced a flight planning decision support system (DSS) for the Beechcraft Super King Air, which is a twin-engine jet prop and is their top-of-the-line airplane. The military C-12B is a Super King Air with the heavy duty landing gear option. The DSS consists of an HP-41C with a custom module. The Beech module, a special keyboard overlay for the HP-41C, and the operator's manual cost $910. The HP-41C is not included in that price, but it is obviously required. A printer is optional. The "Flight Planning Computer", as Beech has named the DSS, operates thirteen programs to aid the pilot during preflight planning and

during flight. Brief descriptions of the thirteen programs are reproduced, in part, from the operator's manual and are contained in Figure III-1. [Ref. 12] The program named SAVE is likely to be the big selling point for the system. SAVE's function is to find the most economical altitude for any flight. In making its selection, SAVE considers (1) the cruise power setting, (2) forecast winds aloft, (3) and fuel required to climb to, cruise at, and descend from each legal altitude available during a flight. SAVE calculates the following: (1) total fuel and total time required for the flight at both the least-fuel and least-time altitudes, and (2) fuel saved and additional time required if the least-fuel option is selected over the least-time option. In the September 1980 issue of AOPA Pilot, M. F. Silitch reports that:

> "Using a flight-planning computer to calculate minimum-fuel altitudes could result in fuel savings of about 6,000 gallons a year for each Super King Air, based on 550 to 600 hours of use." [Ref. 13]

Silitch probably based the 6,000-gallon figure on owners' reports of 10% savings. In cruise flight a Super King Air averages 100 gallons of fuel per hour or 60,000 gallons in 600 hours. It is unclear whether the owners were claiming to have flown 10% more miles on equal amounts of fuel or were consuming 10% less fuel on equal mileage. In either case, assuming the pilot religiously selected the least-fuel option, it would be safe to forecast that Beech's

Figure III-1

Programs in the Beechcraft Flight Planning Computer

Name	Program Description
SAVE:	Gives least-fuel and least-time altitudes and the differences in time and fuel between the two.
CLIMB:	Gives time, fuel, and distance required to cruise climb with zero wind.
CRUISE:	Gives engine torque setting, fuel flow per engine, and true airspeed values for recommended cruise power at 1700 rpm.
DESCENT:	Gives time, fuel, and distance required to descend with zero wind.
RHUMB:	Gives rhumb line navigation distances and constant true heading from departure point to destination.
GREAT:	Gives great circle navigation distance and initial true heading from departure point to destination.
TAS:	Gives Mach number, true outside air temperature, and true airspeed during flight.
WEIGHT:	Advises whether a specific airplane is loaded within center of gravity and weight limits.
COMPUTE:	Works basic flight computer problems, such as distance/time = ground speed, and time X fuel flow = quantity required.
WIND:	Figures in-flight wind true direction and velocity.
TREND:	Provides values of deviation from standard for three engine operating parameters, which can be used as data points to plot engine-condition trend lines.
LOAD:	Loads the empty weight, moment, and other special items for the specific airplane in question into the computer memory.
START:	Sets up calculator prior to first run.

Flight Planning Computer would pay for itself in <u>about</u> the first 150 hours of flight time after its purchase. A pilot does not have to be a computer expert to use the Flight Planning Computer. It is programmed with 65,000 questions/answers [Ref. 13] that lead the pilot through the programs. An example of this technique for each of the thirteen programs is contained in the operator's manual. The initial actions are the same for all programs. First, turn on the HP-41C and push the key called NAME on the Beech keyboard overlay. Second, "NAME PLEASE" will appear in the calculator display. Each of the thirteen programs has a one-word English name and also a two-letter Z-code. To run, for example, the program SAVE, simply key in the letters spelling SAVE, or the code ZA, and press the key named NEXT on the overlay. The display will show the first of the series of questions listed in Figure III-2. After the appropriate value is keyed in and NEXT is pressed, the next question appears. After these questions are all answered, the HP-41C will display "WIND DATA <>", meaning it is determining what wind information is needed for the final solution. Next, a series of wind-related questions will be asked by the calculator. Examples of those questions and their meanings are contained in Figure III-3. The calculator will repeat these three wind-related questions for pertinent altitudes based on the minimum and maximum altitudes specified earlier. Next, "DES P.A. = x,xxx?" (asking for the pressure altitude

Figure III-2

<u>Series of Questions Asked by Program SAVE</u>

Question	Meaning
T.O. WT = xx,xxx?	What is the takeoff weight of the airplane?
T.O.P.A. = x.xxx?	What is the pressure altitude at the takeoff airport?
T.O. TEMP = x?	What is the temperature in degrees Celsius at the takeoff airport?
DIST = x,xxx?	What is the distance of the trip in nautical miles?
TRU CRS = xxx?	What is the true course of the trip?
MN AL = xx,xxx?	What is the minimum altitude the pilot will accept?
MX AL = xx,xxx?	What is the maximum altitude the pilot will accept?

Figure III-3

<u>Temperature and Winds Aloft Questions</u>

Question	Meaning
6K - DIR = xxx?	What is the direction of the winds at 6000 feet in degrees true?
6K - VEL = xx?	What is the velocity of the winds in knots?
6K - TMP = -xx?	What is the temperature in degrees Celsius at 6000 feet. The - sign before the xx in the question reminds the pilot that many of these temperature entries will be negative numbers.

at the destination airport) will appear in the display. After making that entry and pressing NEXT, "STANDBY" will be displayed, meaning the entered data is being processed. After about 75 seconds, data regarding the least-fuel option will be displayed. If "29K,T3:48,F2,069" were displayed, it would mean that the altitude for the least-fuel option would be 29,000 feet, the time enroute would be 3 hours and 48 minutes, and 2,069 pounds of fuel would be consumed. Pressing "NEXT" will cause additional output, such as the recommended power setting at the least-fuel altitude and the altitude, time, fuel, and power setting for the least-time option. Also, the differences in time and fuel between the two options can be displayed. If a printer is available, all the output data is printed after NEXT is pressed. Without a printer, it is necessary to press NEXT several times as there is more output than can be displayed at one time. For each of the programs, error messages are generated and displayed immediately following any input which is outside the normally expected value for that input. Examples of the error messages as they would be displayed are: "TOO HIGH", or "TOO LOW", or "TOO HOT", or "TOO COLD", or "N/A INPUT", or "xxK TOO HIGH" (meaning climb to and descent from this altitude cannot be made without exceeding the total distance specified for the trip), or "xxK R/C LOW" (meaning the rate of climb at or before reaching this altitude is less than 101 feet per minute).

The software for the Flight Planning Computer was written by a Beech employee/pilot named David Horwitz, who has a master's degree in electrical engineering. He did the programming in his own time and estimates the effort required 800 hours. In a telephone interview with this thesis author, Horwitz said he had tried to write similar programs on the HP-65 and the HP-67 but was unsuccessful due to the inherent limitation of those PHHC's. He found the TI-59 could be satisfactorily programmed to computerize aircraft performance data; however, the human interface needed to run the programs was complicated and awkward. Accordingly, it was decided the average general aviation pilot did not have the time, background, or inclination to master such a program. Horwitz acquired one of the first available HP-41C's and found it to be ideal for the task he had in mind. After writing the software, Mr. Horwitz presented the concept to Beech management, who decided to validate the program and market the product as a service to Super King Air owners and operators.

B. MORTAR APPLICATION

The successful testing and introduction of the TI-59 for service with the artillery was described in Chapter II. The operational capability of the PHHC to "perform fire direction functions for mortars" [Ref. 9: p. 1-3] was evaluated during the period 12 December 1978 to 11 May 1979. This

test was made using magnetic cards programmed with ballistic constants. The test revealed that:

> "Dirt and temperature affected the cards and the cards were not universally interchangeable among calculators. At 20 degrees Fahrenheit (F), the calculator would not always read magnetic cards which had been programmed at 65 degrees F. Setting up the calculator usually required two or three attempts to read the cards." [Ref. 9: p. C-1]

In spite of these problems, one of the test assessments was that the PHHC:

> "has the operational capability to perform selected FDC (fire direction center) functions for 81-millimeter and 107-millimeter mortars." [Ref. 9: p. 2-16]

In order to eliminate the problems associated with magnetic cards, the U. S. Army Training and Doctrine Command (TRADOC) Combined Arms Test Activity (TCATA) developed and procured two custom Texas Instruments modules, one for 81-millimeter mortars and one for 107-millimeter mortars. During the period from 3 to 6 March 1980 a Mortar Data Module Firing Program Evaluation was conducted at Fort Hood, Texas. The stated reason for the test was:

> "to determine if the use of a discrete mortar ROM module for the PHHC produced significant changes in the performance of mortar FDC's." [Ref. 14: p. 1]

Specifically, the evaluation compared the performance of FDC's using TI-59's to the performance of FDC's using the standard manual method of computing fire commands. At the Marine Corps' request, an excursion was included in the test scenario so that setup times in the battery-powered, hand-held mode could be evaluated. A major assessment of the

evaluation was that FDC personnel can compute fire commands and other ancillary functions faster and more accurately using the calculator than using the manual method. The shorter FDC setup times for the PHHC, as compared to the manual method, were statistically significant.

As a result of this test, the Army decided to procure PHHC systems for each unit employing mortars. It is expected that the mortar TI-59's will be supplied to Army units by late 1981. A purchase by the Marine Corps is pending.

IV. THE FUTURE OF THE PHHC IN THE MILITARY

Cost and user resistance are the primary and secondary obstacles which inhibit large scale adoption of formal programs using PHHC's. Both of these problems will be analyzed in the following sections.

A. COST

Two different types of costs should be recognized when considering the procurement of any system. One is the non-recurring, developmental costs; the other is the incremental costs associated with purchasing an item after it has been developed. With PHHC's, the non-recurring, developmental cost includes the cost of writing the coded instructions which cause the calculator to perform. This is often referred to as software costs. The per-item price charged by a manufacturer, such as Texas Instruments or Hewlett-Packard, could be thought of as the incremental portion of the cost of funding additional usage of PHHC's.

There are also two different methods of obtaining the software. One way is to contract with a private corporation or consulting group. The other method is to have the software written by in-house, government programmers. Both methods have been used. Examples of the historical costs are presented in the following subsections.

1. Outside Contractor

a. The AV-8A Calculator

Two Hundred Harrier flight performance calculators, described in Chapter II, were procured via a firm fixed price contract between Naval Air Systems Command and McDonald Douglas Aircraft Corporation at a stated cost of $175,000. [Ref. 6] Additional units beyond the initial purchase of 200 were stated to be available at $125.00 each. [Ref. 15] Although not stated, that $125.00 figure was probably only true for the next fifty calculators and for a batch of an additional 250 beyond that. The reason is because Texas Instruments has a minimum charge for fabricating custom modules. That minimum charge is currently $12,500 for 250 modules. The non-recurring, developmental costs would include (1) software costs, (2) cost of designing and fabricating the modified face plate, (3) cost of writing the user's manual, and (4) the cost of designing the special leg strap. Thus, the contract price could be apportioned as follows:

Incremental costs (200 @ $125.00)	$ 25,000
Non-recurring developmental costs	150,000
Total	$175,000

The contract was approved in August 1977, and the calculators were delivered in June 1978.

b. The AV-8C Calculator

The AV-8C is scheduled as a follow-on model to the revolutionary vertical/short takeoff and landing

(V/STOL) close air support jet. McDonald Douglas submitted a bid of $300,000 to provide 200 flight performance PHHC's for the AV-8C. That bid could be apportioned as follows:

Incremental costs (200 @ $150.00)	$ 30,000
Non-recurring developmental costs	270,000
Total	$300,000

In this case, the non-recurring costs include the same items as for the AV-8A calculator except for the leg strap which was not a specification on the AV-8C calculator request for proposal (RFP). The AV-8C calculator contract was not awarded due to uncertainties during 1980 about funding for the aircraft itself.

The following explanation is offered for the significant increase in the bid for the AV-8C calculator over the cost of the AV-8A calculator. Inflation in the 2.5 years would account for a 30% increase above $175,000, an amount equal to $52,500. Thus, 52.5/(300-175) or 42% of the increase can be attributed to rising price levels. The other 58% of the increase was explained by McDonald Douglas as being due to their having lost money on the AV-8A calculator contract. It is certainly necessary for private industry to make a profit. One way to insure that the profit is not excessive is through the use of competition. Competitive bidding is required by the Defense Acquisition Regulations unless one of the seventeen exceptions to the general requirement for competition exists. If an exception is granted, the final price is determined by negotiation, a process

in which cost accounting standards play an important role in determining a fair estimation of the costs the contractor can reasonably expect to encounter.

c. The Beechcraft Flight Planning Computer

While the Beechcraft Flight Planning Computer was certainly not the result of a government contract, it is an example for which a stated price does exist. That price is:

HP-41C	$ 190	[Ref. 2]
Beech Module	910	[Ref. 13]
Price for one	$1100	
Price for 200	$220,000	

It should be noted that a direct comparison between the Beechcraft Flight Planning Computer and the AV-8A Harrier calculator is not possible. The former has much more capacity and the latter is constrained by the lack of alphanumerics in the TI-58. In other words, Harrier pilots have to learn which buttons control which functions and in what order the buttons must be pressed, whereas Beechcraft pilots merely have to respond to abbreviated English questions that prompt each task.

d. The Fleet Mission Program Library

This library is maintained as a function of the Naval Tactical Support Activity whose headquarters is in Silver Springs, Maryland. The library is a collection of HP-67 programs which are used to aid a variety of the U. S. Navy's tactical missions. The only programs in that library

which have application in the U. S. Marine Corps are those pertaining to celestial navigation, which could possibly be used by Marine KC-130 squadrons. The programs which deal with weight and balance of the P-3 and S-3 aircraft could be modified for use on USMC aircraft.

The labor-related cost of this program can be traced to a contract between the Navy and the Atlantic Analysis Corporation. In return for $45,000, the Navy receives one man year of programming assistance. This assistance involves (1) reviewing requests from the fleet for specific program applications, (2) writing the software for approved requests, (3) validating programs submitted by users for inclusion in the library, and (4) updating current programs as changes in procedures and equipment occurr. On an average, this contract produces twelve new, validated, or modified programs per year. An HP-67 program can be up to 224 steps in length. [Ref. 1: p. 78]

2. In-house, Government Programmers

The artillery PHHC and the mortar PHHC are the primary examples of where the military has used its own employee programmers to write software for a formal, large-scale, PHHC project.

Cost accounting systems enable most large corporations to accurately record labor-related and material-related costs and to allocate overhead costs to each project. Without a signicant amount of research (and permission/

cooperation of the the U. S. Army to perform the research), it would not be possible in these examples to recapture the exact total cost of each project. The reason this information is not more readily available is because the Army did not elect to declare either the artillery PHHC or the mortar PHHC to be a "special interest item" as is done in a large procurement such as for tanks and other weapon systems. If that had been done, each item of cost would have been charged to an account code reserved for the special interest item.

In the case of the artillery and mortar calculators, the only formal records which can be analyzed regarding the non-recurring, developmental costs are those maintained in accordance with the U. S. Army Training and Doctrine Command (TRADOC) Management Information System (TRAMIS). Under the current generation TRAMIS, man days (MD) of effort are charged to an action control number (ACN). TRAMIS is under revision; TRAMIS-Improved, scheduled to come on line in mid 1981, will capture not only the man hours but also the pay grade of the worker. Currently however, TRAMIS data is contaminated in that it includes man days from employees at several different wage rates. A labor rate standard, which takes into consideration the mix of pay grades and MD, does not exist. Thus, it is not possible to determine an exact total for the labor-related costs. No material-related costs are available. Nor is it possible to make an alloca-

tion of the overhead costs. Travel costs might be obtainable, but only by manually examining all the travel orders written during the period and being able to pick out the travel made in conjunction with the calculator project.

In the case of the artillery calculator project, two different ACN's were actually used. Fort Sill officials established ACN 51665 during 1978 only to later discover that TRADOC had assigned ACN 36808 for the same project. Accordingly, ACN 51665 was not used after Fiscal Year (FY) 1979. The following data has been extracted from TRAMIS records.

	FY 1978	FY 1979	FY 1980
ACN 51665	92 MD	45 MD	0
ACN 36808	0	417 MD	395 MD
FY Totals	92 MD	462 MD	395 MD

The MD accounted for above might be thought of as applying to the software developmental time required by three separate subprojects of the main project. Those three subprojects would be: (1) development of the prototype module used during the 12 December 1978 to 11 May 1979 test, (2) development of the nine modules now available to artillery units, and (3) development of additional modules for expanded application of the artillery PHHC system. Unfortunately, the aggregated MD do not allow for that distinction. In an attempt to relate MD of programming effort to a specific module, a telephone interview was conducted with Mr. Donald J. Giuliano.

Mr. Giuliano, who has a master's degree in mathematics, did the programming for the prototype module. He recalls that the time spent on that programming task was from the last week in August to the last week in September of 1978, or about twenty-two working days. Validation of the program and emulation, a step required by Texas Instruments for fabrication of the modules, required another three weeks. During this time, Giuliano was in pay grade GS 9 step 1. It should also be noted that prior to starting the programming effort, Giuliano attended classes at the Field Artillery School to become acquainted with artillery terms, concepts, and procedures. His employment at Fort Sill actually started in March of 1978. Viewed in a narrow sense, one might conclude that the direct labor cost to the Army was less than two months pay and benefits or about $5,000. However, another school of thought would attempt to include all the cost the Army would not have incurred had they contracted out the same programming effort. That estimation could include Giuliano's wages and benefits from March 1978 to January 1979, when he became actively involved in programming six of the nine modules in current use. Even using that broad definition of the total discretionary cost, simple calculation shows the total direct labor cost to be not more than $25,000. A rough approximation of the overhead cost associated with the prototype module might be another $25,000. The direct material cost involved in this

software development would probably amount to less than $5,000. Added together, we have a sum of $55,000.

One is now attempted to compare this $55,000 with the $150,000 derived to be the developmental cost of the Harrier calculator. However, while on the surface that might appear to be valid comparison of the developmental cost of two custom modules, the differentiating factors should be considered. The computerization of the Harrier performance data was a new effort. Not only was it a new effort for the Harrier, it had never been done for any aircraft. By contrast, artillery aiming solutions had previously been computerized for FADAC and also for earlier evolutions of TI-59 programs on magnetic cards.

In his Naval Postgraduate School thesis, Koger wrote nine different TI-59 programs which computerized several of the A-7 aircraft performance charts. [Ref. 4: pp. 90-138] These nine programs were written in such a manner so that they would all fit within a 5000-step Texas Instruments module. In a letter solicited by this author, Koger estimated his programming effort required 400 man hours, plus or minus 25%. This figure is reinforced by Seigel, who, in a telephone interview, estimated such an effort would require two man months, which computes to 352 man hours figured on the basis of forty-four, eight-hour days. Applying the $45,000 contract between the Atlantic Analysis Corporation and the Navy as a guide to the annual cost of a programmer's ser-

vices, and using Koger's high estimate (400 + 25% = 500 = 2.8 man months @ 176 hours per month), it would appear that the cost of writing the software for an aviation-peculiar Texas Instruments module is approximately $10,500. Extensive validation and emulation would perhaps require an additional three man months, but the total direct labor cost should still be not more than $25,000. If the overhead cost were the same as the direct labor cost and if the direct material cost were $5,000, the total would be $55,000. That is the same cost as for the prototype artillery module, even though different avenues were used to arrive at the figures. Admittedly, many of the assumptions, such as the cost of overhead, are only broad estimates and cannot be verified because the industrial firms with experience in this field consider the information to be proprietary.

The Naval Weapons Center at China Lake, California certainly has the expertise to write PHHC software to computerize NATOPS performance data, but as yet, they have not been asked to perform such a task.

In addition, it should be noted that the 182 pages of performance charts, graphs, and instructions in the typical NATOPS flight manual did not come free. While that is a sunk cost in existing aircraft, it is certainly reasonable to suggest that for future aircraft the cost of generating NATOPS performance charts could be applied toward the cost of buying PHHC's with custom modules. It is not expected

that aircrews will be agreeable to giving up their paper charts until they have had more opportunity to be personally convinced of the viability of the PHHC to do the job. Thus, elimination of the traditional charts and graphs is a long term, rather than a short term, goal.

In conclusion to this section on the cost of formal PHHC systems, it should be stated that while using in-house, government programmers appears to cost less than it would cost to contract out the software development, this apparent lower cost cannot be proven. If the Army had chosen to account for the developmental cost via their job order cost accounting system, much more precise information would be available. This precise information, after being adjusted for inflation, could have been used as a benchmark for comparison with contractors' bids on the software development of future PHHC sytems within the military.

B. USER RESISTANCE

While cost is the undisputed king in the list of obstacles to additional formal programs using PHHC's, a smaller, but not to be ignored, obstacle could be termed "user resistance." User resistance to potential computerization of NATOPS performance data has been expressed by reluctant naval aviators and naval flight officers in the following manner: (1) "a crutch," (2) "aircrews will never learn to use NATOPS charts," (3) "nice to have but not essential,"

and (4) "this may foster dependency while concurrently reducing a pilot's ability to use NATOPS charts properly." These objections are similar to those probably voiced by certain people years ago when asked by innovators if they would trade their horse and buggy for a car. The ready acceptance of PHHC's by Harrier pilots and Beechcraft pilots is reliable evidence that this new decision support system is a vast improvement. It is anticipated that the reluctant among us will become comfortable with PHHC's after seeing firsthand the time savings and increased accuracy which can be obtained by them.

V. INFORMAL PROGRAMS

There is great opportunity to use PHHC's for a variety of tasks. They can reduce the burden inherent in the manual manipulation of numbers. Their perfect accuracy is degraded only by the person pressing the keys. Even this problem can be diminished by creative programming which generates error codes/messages for inputs which are larger or smaller than the normal parameters for that specific input. The PHHC's potential uses are limited only by the ingenuity of those individuals having access to PHHC's. Several military officers with whom this author is acquainted have purchased PHHC's and have written programs to help them do their job better and faster. With TI-59's soon being available in USMC artillery batteries and perhaps later being available in mortar platoons also, more individuals will have a chance to harness the power of the PHHC. The Harrier calculator, with its modified face plate, is difficult to use as a conventional PHHC; however, it would be fairly easy to design an overlay which could be used to temporarily restore its original TI-58 keyboard appearance. This would enable its custodian to use it not only for flight planning but also for administrative problems. Even its flight planning capacity could be expanded via the Texas Instruments aviation module, which is discussed in more detail in Appendix B.

Calculator Clout: Methods of Programmable Calculators by M. D. Weir, who is an Associate Professor at the Naval Postgraduate School, is recommended to those wanting to learn how to program the TI-58/TI-59. The book presents the basic elements of programming, including flow charts, looping and branching, subroutines and Master Library programs, indirect addressing, and the use of magnetic cards. There are numerous examples illustrating programming techniques to solve problems in business mathematics, algebra and trigonometry, basic calculus, and random number methods.

The following four sections will explain programs which can be used to solve arithmetic-related difficulties. Three of the program were written by military officers; the other by Texas Instruments' programmers.

A. NAVAL GUNFIRE PLAN FOR AMPHIBIOUS LANDINGS

Navy Lieutenant P. M. Loring, a Naval Gunfire Liaison Officer at Camp Lejeune, North Carolina, wrote a program for his HP-29C to reduce the time it takes him to complete the naval gunfire portion of the planning for an amphibious landing. This planning includes measuring the bearing and distance from the anticipated location of the naval gunfire ship to numerous targets in the amphibious objective area. He found that when using the program it took only ten minutes to do the planning for twenty-seven targets; whereas, it had required two hours to do it manually.

Loring also used the program after coming ashore during numerous exercises while attached to Battalion Landing Team 3/8 during its deployment with Landing Force Sixth Fleet in the Mediterranean Sea. The HP-29C is not card programmable, but it does have constant memory, which permits its user to turn it off without losing the program. By having two sets of nickel-cadmium batteries, which could be recharged by the 120 volt generator used to provide power for the Battalion Command Post, Loring expected to be able to use this program for extended periods of time.

Although the Naval Gunfire Liaison Officers are operationally controlled by the infantry commander, they are usually administratively attached to an artillery unit. Since several Marine artillery batteries will soon be receiving TI-59's, Loring's Naval Gunfire Planning Program has been translated into Texas Instruments-type programming steps so that the program will be available for wider use. Program listings and the instructions for using both the HP-29C and the TI-58/TI-59 versions of the program are contained in Appendix A.

B. AVIATION FLIGHT PLANNING

Captain J. E. Bull served during 1978 as an A-6 aircraft bombardier navigator with Marine All Weather Attack Squadron 533. One of Bull's collateral duties is known as "squadron navigation officer." Bull, then a First Lieutenant, had

purchased his own TI-58 and printer and the Texas Instruments (TI) Aviation Module. When tasked with the navigation and fuel planning for a squadron deployment from Cherry Point, North Carolina to Fallon, Nevada, Bull found the TI Aviation Module to be a great help in making the required computations. The deployment planning included in-flight refueling, which would permit a non-stop flight from Cherry Point to Fallon and also for the return flight. This use of airborne tankers intensified the need for precise time checkpoints and accurate fuel figures. Appendix B contains a copy of the printer tape generated for that return flight. The tape was generated by the Aviation (AV) Module's program number four (AV-04), which is entitled "Long Range Flight Plan." AV-04 is described in Appendix B.

Bull also found considerable use for AV-02, "Flight Plan With Wind." AV-02 determines the magnetic heading for the pilot to fly and the resultant ground speed based on (1) wind speed, (2) wind direction, (3) magnetic compass variation, (4) true airspeed, (5) and true course. Using the fuel flow rate, the leg distance, the departure time, and the ground speed, AV-02 calculates the flying time, the estimated arrival time at the next fix, and the fuel consumption for each leg. After making the above calculations, AV-02 also computes the total time enroute and the total fuel required thus far in the flight. In a letter solicited by this author, Bull wrote that it requires forty-five

seconds for his TI-58 to make the above calculations. By comparison, he reported that it takes ninety seconds using a CR-3, which is an aviation-peculiar, circular slide rule. It is not uncommon for a flight to have twenty different legs. The Aviation Module would cut fifteen minutes off the planing time required for such a flight.

Bull noted that AV-11, "Great Circle Flying", would be especially useful in preparing for a transoceanic flight. The characteristics of AV-11 and the other twenty-two programs on the Aviation Module are all explained in detail in the manual supplied with the module. The module currently retails for $35.00.

C. CALCULATION OF PROMOTION COMPOSITE SCORES

Promotion to Corporal and Sergeant in the USMC is determined by a composite score which is calculated from such things as (1) rifle marksmanship score, (2) physical fitness test score, (3) number of essential subjects tests passed, (4) average duty proficiency score, (5) average conduct score, (6) time in grade, (7) time in service, (8) outside education courses completed, and (9) bonus points for having completed certain training. To the uninitiated, this might appear to be a simple addition exercise; it is not. The procedures to be used are detailed in Marine Corps Order P1400.29B. It is somewhat complicated, and consequently, error rates reaching as high as 4% have occasionally been

known to occur. Depending on the skill and experience of the person calculating the composite score, the time required ranges from two minutes to five minutes. In addition, each calculation should be checked by a supervisor, which means another two minutes. An infantry battalion will have about 200 Lance Corporals and Corporals on whom a composite score must be computed each promotion period, of which there are usually four each year.

First Lieutenant Edward A. Bream wrote a TI-59 program to automate the composite score calculation. He found that using the program reduced to less than a minute the time required to calcuate each Marine's composite score. By having two different persons compute each score and compare the results, mistakes caused by input errors are easily detected before the scores are published. A slightly modified and partially optimized version of Bream's program and instructions for using it are presented in Appendix C. The program requires nearly all the capacity of a TI-59, which precludes the generating of error codes for spurious entries. This is not a problem as each score is calculated twice anyway, and any differences can be investigated and resolved.

D. CALCULATION OF PHYSICAL FITNESS TEST SCORES

The USMC physical fitness test (PFT) for males consists of a 3-mile run, two minutes of sit ups, and maximum possi-

ble pull ups. The raw score from each event is converted to a standard score by reference to a table in Marine Corps Order 6100.3H. To determine the overall PFT score, the training clerk extracts a number from the table, writes it on the score sheet, and adds up the three scores, a fairly simple task. In fact, the table's supporting algorithm is so uncomplicated that many Marines figure their score without looking at the table. Therefore, it was not difficult to write a TI-59 program which converts raw scores for each PFT event into standard scores and sums the three, arriving at the total. That program is explained in Appendix D and is offered as an example to encourage those who might be reluctant to try their skill at writing PHHC software.

VI. CONCLUSIONS AND RECOMMENDATIONS

The use of programmable hand-held calculators (PHHC's) in the operating forces of the U. S. Marine Corps has been initiated and survived operational testing. AV-8A Harrier pilots have been using a PHHC with a custom module since 1978. Its increased accuracy over conventional performance charts is widely acknowledged. The U. S. Army developed custom modules for use by artillery and mortar fire direction centers. Soldiers are enthusiastic about the PHHC's portability and reliability. They are quick to point out the speed with which it performs. The most obvious areas for additional usage are other aircraft communities and other artillery cannons/types of ammunition.

The major obstacle to more wide-spread adoption of PHHC systems is the software costs. An important question is whether the software development should be done by government programmers or by private contractors. It is recommended that strict cost accounting standards be used on any future projects where government programmers write the software for PHHC modules. This procedure will create a body of data regarding those costs. Alternatively, if the programming effort is contracted to private industry, competitive bidding should be employed unless an exception is granted in accordance with the Defense Acquisition Regulations.

For those who fear that computerizing aircraft performance data will require a new PHHC module with each NATOPS manual revision, it is pointed out that improved engines are only procured about once every ten years. Such a change requires flight testing to validate performance curves whether the end product is to be a revised chart in the NATOPS manual or a new module for the PHHC.

A cost-benefit analysis regarding PHHC's is fairly easy to do for transport type aircraft. Data obtained from Beechcraft Super King Air owners indicate a 10% fuel savings, which means the calculator paid for itself in less than three months of average use. For tactical military aircraft, tactics rather than economy often dictates the altitude at which an aircraft will fly its mission. However, even these aircraft conduct a certain amount of training in the cross country mode where 10% fuel savings could mean a lot of money. A-6 squadrons average about thirty hours per aircraft per month. If only three hours per aircraft per month were available for cross country training and if a Beechcraft-type PHHC were used to pick the most economical altitude, the 10% fuel savings would translate to about \$200 per aircraft per month at \$1.00 per gallon of jet fuel. Thus, it might take six months for the fuel savings to pay for PHHC's for the whole fleet of A-6's. A similar analysis could be made for other tactical communities. For aircraft which enjoy lower rates of fuel consumption, the

payback period would, of course, be longer. A fringe benefit is that tactically-oriented charts could also be computerized on the same module. Another way of looking at the costs and benefits is to predict that PHHC's, being easier, quicker, and more accurate to use, will probably prevent at least one accident during their life. One million dollars saved by one less accident would pay for all that aircraft community's calculators several times over.

APPENDIX A

A CALCULATOR PROGRAM WHICH DECREASES THE TIME NEEDED TO DO THE NAVAL GUNFIRE PLAN FOR AN AMPHIBIOUS LANDING

This appendix contains the program steps and the program operating instructions for the Naval Gunfire Planning Program introduced in Chapter V. The program has four primary subroutines. Their purposes are: (1) to compute gun-to-target range in meters and bearing in mils grid given six-digit grid coordinates of the gun and a target, (2) to compute a six-digit grid coordinate given range and bearing data from a known point, (3) to convert mils grid to degrees true, and (4) to compute the time of flight for a 5"/54 round given the range. The original HP-29C program was translated to Texas Instruments program language. Instructions on how to run the HP-29C program are presented first, followed by the HP-29C program listing and storage register uses. After that are the TI-58/TI-59 operating instructions, storage register uses, and program listing.

Operating Instructions for the HP-29C Naval Gunfire Planning Program

Step	Instruction/Type of Data to Enter/ Subroutine Name	Input	Press Key(s)	Output
1.	Key in program			

Operating Instructions for the

HP-29C Naval Gunfire Planning Program - Continued

Step	Instruction/Type of Data to Enter/ Subroutine Name	Input	Press Key(s)	Output
2.	Initialize		GSB 0	
3.a.	Gun position X coordinate	xxx	STO 2	
b.	Gun position Y coordinate	yyy	STO 4	
c.	Grid to true declination (E= -)	mils	STO 8	
d.	Mils to degrees conversion	6400÷360	STO 9	
e.	5"/54 max range	23000	STO .0	
f.	5"/38 max range	15500	STO .1	
g.	Meters to feet conversion	3.280839895	STO .2	
h.	5"/54 max time of flight	167.78	STO .3	
4.	See note 1			
5.a.	Range and bearing		GSB 1	
b.	Target position X coordinate	xxx	R/S	xxx X 100
c.	Target position Y coordinate	yyy	R/S	range in meters
d.	Compute bearing		R/S	mils grid
6.a.	Grid coordinates		GSB 2	
b.	Enter bearing	mils grid	R/S	
c.	Enter range	meters	R/S	X location
d.	Determine Y		R/S	Y location

Operating Instructions for the HP-29C Naval Gunfire Planning Program - Concluded

Step	Instruction/Type of Data to Enter/ Subroutine Name	Input	Press Key(s)	Output
7.a.	Mils grid to degrees true		GSB 3	
b.	Bearing	mils grid	R/S	degrees
8.a.	Time of flight		GSB 4	
b.	Range	meters	R/S	seconds

Note 1.
a. Use step 5 to compute range and bearing information.
b. Use step 6 to compute grid coordinates.
c. Use step 7 to convert mils grid to degrees true.
d. Use step 8 to compute time of flight for a 5"/54 round.
e. For a different problem, simply enter the new data in accordance with the applicable step instructions.

Program Listing for the HP-29C Naval Gunfire Planning Program

Step	Instruction	Step	Instruction	Step	Instruction
1.	LBL 0	20.	STO 3	39.	GSB 7
2.	GRAD	21.	RCL 1	40.	RCL 7
3.	FIX 0	22.	RCL 2	41.	÷
4.	6	23.	-	42.	R/S
5.	4	24.	RCL 3	43.	P to R
6.	0	25.	RCL 4	44.	STO 3
7.	0	26.	-	45.	xy EX
8.	STO 5	27.	R to P	46.	STO 1
9.	2	28.	R/S	47.	RCL 4
10.	÷	29.	xy EX	48.	RCL 3
11.	STO 6	30.	RCL 7	49.	+
12.	1	31.	X	50.	GSB 6
13.	6	32.	GSB 8	51.	RCL 2
14.	STO 7	33.	GTO 1	52.	RCL 1
15.	RTN	34.	LBL 2	53.	+
16.	LBL 1	35.	R/S	54.	GSB 6
17.	GSB 9	36.	RCL 6	55.	R/S
18.	STO 1	37.	xy EX	56.	xy EX
19.	GSB 9	38.	x > y	57.	GTO 2

Program Listing for the

HP-29C Naval Gunfire Planning Program - Concluded

Step	Instruction	Step	Instruction	Step	Instruction
58.	LBL 9	70.	RTN	82.	RCL 8
59.	R/S	71.	LBL 7	83.	+
60.	ENTER	72.	RCL 5	84.	RCL 9
61.	EEX	73.	-	85.	÷
62.	2	74.	RTN	86.	GTO 3
63.	X	75.	LBL 6	87.	LBL 4
64.	RTN	76.	EEX	88.	R/S
65.	LBL 8	77.	2	89.	RCL .0
66.	x > 0	78.	÷	90.	÷
67.	RTN	79.	RTN	91.	RCL .3
68.	RCL 5	80.	LBL 3	92.	X
69.	+	81.	R/S	93.	GTO 4

Contents of the Storage Registers in the

HP-29C Naval Gunfire Planning Program

Register Number	Contents
0	not used
1	target's X coordinates
2	gun's X coordinates
3	target's Y coordinates
4	gun's Y coordinates
5	6400 (mils in 360°)
6	3200 (mils in 180°)
7	16 (mils per grad)
8	map grid to true declination
9	6400 ÷ 360
.0	23000 (max range of 5"/54)
.1	15500 (max range of 5"/38)
.2	meter to feet conversion
.3	167.78 (maximum time of flight in seconds for a 5"/54 round)

Operating Instructions for the TI-58/59 Naval Gunfire Planning Program

Step	Instruction/Type of Data to Enter/ Subroutine Name	Input	Press Key	Display
1.	Read magnetic card or key in program			
2.	Initialize		E"	number 168
3.a.	Gun position X coordinate	xxx	A	same as input
b.	Gun position Y coordinate	yyy	R/S	same as input
c.	Grid to true declination (E= -)	mils	R/S	same as input
4.	See Note 1			
5.a.	Range and bearing subroutine	target xxx	B	same as input
b.		target yyy	R/S	range in meters
c.			R/S	bearing in mils
6.a.	Grid coordinates subroutine	range in meters	C	same as input
b.		bearing in mils	R/S	xxx of the objective
c.			R/S	yyy of the objective
7.	Mils grid to degrees true	mils	D	degrees
8.	Time of flight for 5"/54 round	range in meters	E	time in seconds

Note 1.
a. Use step 5 to compute range and bearing information.
b. Use step 6 to compute grid coordinates.

c. Use step 7 to convert mils grid to degrees true.
d. Use step 8 to compute time of flight for a 5"/54 round.
e. For a different problem, simply enter the new data in accordance with the applicable step instructions.

Note 2. If a printer is used, each input entry and all output data for steps 3, 5, 6, 7, and 8 will be printed.

* *

Contents of the Storage Registers in the TI-58/59 Naval Gunfire Planning Program

Register Number	Contents
0	not used
1	target's X coordinates
2	gun's X coordinates
3	target's Y coordinates
4	gun's Y coordinates
5	not used
6	not used
7	not used
8	map grid to true declination
9	6400 ÷ 360
10	23000 (max range of 5"/54)
11	15500 (max range of 5"/38)
12	meter to feet conversion
13	167.78 (maximum time of flight in seconds for a 5"/54 round)
14	used during step 5
15	used during step 6

* *

The following pages of this appendix contain the program listing for the TI-58/59 Naval Gunfire Planning Program.

000	76	LBL
001	12	B
002	98	ADV
003	99	PRT
004	42	STO
005	01	01
006	91	R/S
007	99	PRT
008	42	STO
009	03	03
010	75	-
011	43	RCL
012	04	04
013	95	=
014	32	X:T
015	43	RCL
016	01	01
017	75	-
018	43	RCL
019	02	02
020	95	=
021	22	INV
022	37	P/R
023	42	STO
024	14	14
025	32	X:T
026	65	×
027	01	1
028	00	0
029	00	0
030	95	=
031	99	PRT
032	91	R/S
033	00	0
034	32	X:T
035	43	RCL
036	14	14
037	67	EQ
038	97	DSZ
039	22	INV
040	77	GE
041	97	DSZ
042	43	RCL
043	14	14
044	65	×
045	43	RCL
046	09	09
047	95	=
048	99	PRT
049	91	R/S
050	76	LBL
051	97	DSZ
052	85	+
053	03	3
054	06	6
055	00	0
056	95	=
057	65	×
058	43	RCL
059	09	09
060	95	=
061	99	PRT
062	91	R/S
063	76	LBL
064	11	A
065	98	ADV
066	99	PRT
067	42	STO
068	02	02
069	91	R/S
070	99	PRT
071	42	STO
072	04	04
073	91	R/S
074	99	PRT
075	42	STO
076	08	08
077	91	R/S
078	76	LBL
079	10	E'
080	47	CMS
081	58	FIX
082	00	00
083	06	6
084	04	4
085	00	0
086	55	÷
087	03	3
088	06	6
089	95	=
090	42	STO
091	09	09
092	02	2
093	03	3
094	00	0
095	00	0
096	00	0
097	42	STO

```
098  10   10
099  01   1
100  05   5
101  05   5
102  00   0
103  00   0
104  42  STO
105  11   11
106  03   3
107  93   .
108  02   2
109  08   8
110  00   0
111  08   8
112  03   3
113  09   9
114  08   8
115  09   9
116  05   5
117  42  STO
118  12   12
119  01   1
120  06   6
121  07   7
122  93   .
123  07   7
124  08   8
125  42  STO
126  13   13
127  98  ADV
128  91  R/S
129  76  LBL
130  13   C
131  42  STO
132  15   15
133  98  ADV
134  99  PRT
135  32  X:T
136  43  RCL
137  15   15
138  91  R/S
139  99  PRT
140  55   ÷
141  43  RCL
142  09   09
143  95   =
144  37  P/R
145  55   ÷
146  01   1
147  00   0
148  00   0
149  95   =
150  85   +
151  43  RCL
152  02   02
153  95   =
154  99  PRT
155  91  R/S
156  32  X:T
157  55   ÷
158  01   1
159  00   0
160  00   0
161  95   =
162  85   +
163  43  RCL
164  04   04
165  95   =
166  99  PRT
167  91  R/S
168  76  LBL
169  14   D
170  98  ADV
171  99  PRT
172  85   +
173  43  RCL
174  08   08
175  95   =
176  55   ÷
177  43  RCL
178  09   09
179  95   =
180  32  X:T
181  00   0
182  77   GE
183  87  IFF
184  32  X:T
185  99  PRT
186  91  R/S
187  76  LBL
188  87  IFF
189  32  X:T
190  85   +
191  03   3
192  06   6
193  00   0
194  95   =
195  99  PRT
```

```
196  91 R/S
197  76 LBL
198  15  E
199  98 ADV
200  99 PRT
201  55  ÷
202  43 RCL
203  10  10
204  65  ×
205  43 RCL
206  13  13
207  95  =
208  99 PRT
209  91 R/S
```

APPENDIX B

FLIGHT PLANNING
WITH AN OFF-THE-SHELF TEXAS INSTRUMENTS AVIATION MODULE

This appendix will explain the input and output data associated with the Texas Instruments Aviation Module (AV) program 04 (AV-04). As mentioned in Chapter V, AV-04 was used during the planning for a Marine All Weather Attack Squadron 533 (VMA AW 533) deployment from Cherry Point, North Carolina to Fallon, Nevada during 1978. AV-04 requires that a printer be used with the TI-58 or TI-59. The abbreviations on the printer tape and in the following text are defined as:

WP = waypoint
LAT = latitude
LON = longitude
GS = ground speed in nautical miles per hour
FUEL = fuel in pounds at the beginning of the trip/leg
BURN = fuel flow rate in pounds
DIST = distance in nautical miles
ETD = estimated time of departure
ETE = estimated time enroute for the trip/leg
ETA = estimated time of arrival
EFR = estimated fuel required
EFL = estimated fuel level at the end of the trip/leg
LEG = the number of the leg to which the data pertains
DLAT = degrees of latitude
DLON = degrees of longitude
TDST = total distance so far in the trip
TC = true course for that leg

LON, LAT, DLAT, and DLON are expressed in DD.MMSS, where DD means degrees, MM means minutes, and SS means seconds. ETD and ETA are expressed by reference to the 24-hour military

clock and are coded HH.MMSS, where HH is the hour, MM is the minutes past the HH, and SS is the seconds past the minute. The program is divided into three parts. First, the LON and LAT of each WP are entered in order into the TI-58/TI-59 and are printed in a group along with the WP number. Second, the average GS for the whole trip, FUEL, BURN, and ETD for the trip are entered. In response, DIST, ETE, ETA, EFR, and EFL are computed and printed. In this example, EFL is a negative number because in-flight refueling will be conducted. Third, for each leg, the GS and BURN are entered if they differ from the values used on the previous leg. Also entered during this third phase are the new FUEL and the new ETD if they differ from the EFL and ETA values for the previous leg. A new value for FUEL was entered on LEG 11 due to the aerial refueling. The output data for each leg in the third phase are LEG, DLAT, DLON, DIST, TDST, TC, ETE, ETA, EFR, AND EFL. The input and the output data are printed in groups by LEG. On the following pages of this appendix is a copy of the printer tape generated during the planning for the VMA AW 533 return trip from Fallon to Cherry Point.

LONG RANGE FLT PLAN

0.0000	WP
39.2500	LAT
118.4200	LON
1.0000	WP
39.0158	LAT
117.1640	LON
2.0000	WP
38.1500	LAT
114.2400	LON
3.0000	WP
37.4100	LAT
112.1800	LON
4.0000	WP
36.4500	LAT
108.0600	LON
5.0000	WP
35.3900	LAT
105.0800	LON
6.0000	WP
35.1700	LAT
101.3800	LON
7.0000	WP
35.2318	LAT
99.1147	LON
8.0000	WP
35.2418	LAT
98.4830	LON
9.0000	WP
35.2700	LAT
97.4600	LON
10.0000	WP
35.0718	LAT
95.2213	LON
11.0000	WP
35.0321	LAT
94.5318	LON
12.0000	WP
34.4100	LAT
92.1100	LON
13.0000	WP
35.0400	LAT
89.5400	LON
14.0000	WP
34.5800	LAT
85.0900	LON
15.0000	WP
35.0200	LAT
81.5600	LON
16.0000	WP
34.5500	LAT
78.0608	LON
17.0000	WP
34.5400	LAT
76.5300	LON
400.0000	GS
19000.0000	FUEL
4500.0000	BURN
14.0000	ETD
1999.9031	DIST
4.5959	ETE
18.5959	ETA
22498.9097	EFR
-3498.9097	EFL

382.0000	GS
13610.0000	BURN
1.0000	LEG
39.0158	DLAT
117.1640	DLON
70.0022	DIST
70.0022	TDST
108.7594	TC
0.1060	ETE
14.1060	ETA
2494.0577	EFR
16505.9423	EFL

450.0000	GS
4300.0000	BURN
2.0000	LEG
38.1500	DLAT
114.2400	DLON
142.8007	DIST
212.8029	TDST
108.2982	TC
0.1902	ETE
14.3002	ETA
1364.5398	EFR
15141.4025	EFL

3.0000	LEG
37.4060	DLAT
112.1800	DLON
104.9890	DIST
317.7919	TDST
108.2469	TC
0.1360	ETE
14.4402	ETA
1003.2283	EFR
14138.1742	EFL

4.0000	LEG
36.4500	DLAT
108.0600	DLON
208.3265	DIST
526.1184	TDST
104.3144	TC
0.2746	ETE
15.1148	ETA
1990.6752	EFR
12147.4991	EFL

5.0000	LEG
35.3900	DLAT
105.0760	DLON
158.0661	DIST
684.1844	TDST
113.7967	TC
0.2105	ETE
15.3253	ETA
1510.4091	EFR
10637.0899	EFL

6.0000	LEG
35.[illegible]660	DLAT
101.3760	DLON
172.4347	DIST
856.6191	TDST
96.3117	TC
0.2260	ETE
15.5553	ETA
1647.7091	EFR
8989.3809	EFL

7.0000	LEG
35.2318	DLAT
99.1147	DLON
119.4400	[illegible]
976.0634	TDST
86.2723	TC
0.1555	ETE
16.1148	ETA
1141.3467	EFR
7848.0341	EFL

420.0000	GS
2000.0000	BURN
8.0000	LEG
35.2410	DLAT
98.4930	DLON
19.0060	DIST
995.0694	TDST
86.8716	TC
0.0483	ETE
16.1631	ETA
90.5947	EFR
7757.[illegible]	EFL

340.0000	GS
6000.0000	BURN
9.0000	LEG
35.2700	DLAT
97.4600	DLON
50.9994	DIST
1046.0677	TDST
86.6634	TC
0.0900	ETE
16.2331	ETA
899.9892	EFR
6857.5402	EFL

10.0000	LEG
35.0718	DLAT
95.2213	DLON
119.0061	DIST
1165.0739	TDST
98.8346	TC
0.2100	ETE
16.4431	ETA
2100.1083	EFR
4757.4319	EFL

400.0000	GS
18000.0000	FUEL
7200.0000	BURN
11.0000	LEG
35.0321	DLAT
94.5318	DLON
23.9888	DIST
1189.0627	TDST
99.3389	TC
0.0336	ETE
16.4807	ETA
431.7991	EFR
17568.2009	EFL

450.0000	GS
4300.0000	BURN
12.0000	LEG
34.4060	DLAT
92.1060	DLON
135.0180	DIST
1324.0807	TDST
98.7528	TC
0.1800	ETE
17.0607	ETA
1290.1719	EFR
16278.0290	EFL

13.0000	LEG
35.0400	DLAT
89.5860	DLON
110.7059	DIST
1434.7866	TDST
77.3817	TC
0.1446	ETE
17.2053	ETA
1057.8562	EFR
15220.1727	EFL

14.0000	LEG
34.5000	DLAT
85.09[illegible]	DLON
237.5562	DIST
1672.3448	TDST
90.0590	TC
0.3140	ETE
17.52[illegible]3	ETA
2270.0007	EFR
12950.1721	EFL

15.0000	LEG
35.0160	DLAT
81.5560	DLON
158.1461	DIST
1830.4349	TDST
87.[illegible]	TC
0.[illegible]	ETE
18.1[illegible]	ETA
1511.1164	EFR
11439.[illegible]	EFL

16.0000	LEG
34.5500	DLAT
78.0608	DLON
188.4717	DIST
2018.9566	TDST
91.0293	TC
0.2508	ETE
18.3846	ETA
1800.9517	EFR
9638.1040	EFL

420.0000	GS
2000.0000	BURN
17.0000	LEG
34.5400	DLAT
76.5260	DLON
59.9823	DIST
2078.9389	TDST
90.6064	TC
0.0834	ETE
18.4720	ETA
285.6301	EFR
9352.4739	EFL

APPENDIX C

A CALCULATOR PROGRAM WHICH COMPUTES THE COMPOSITE SCORE USED IN THE CORPORALS' AND SERGEANTS' PROMOTION SYSTEM

This appendix contains: (1) the format specified by the Marine Corps Promotion Manual for use in recording the scores and the derived ratings applicable to each factor in the composite score, (2) instructions for using a TI-59 to calculate the composite score, (3) a description of how the TI-59's data registers are used, (4) location and purpose of each label used in the program, and (5) the program listing.

Using a TI-59 makes it possible to reduce both the required calculation time and the inherent error rate in non-automated procedures. The program works with or without a printer. The advantages of using a printer are: (1) Since all input data is echo printed, it is easier to locate errors caused by spurious entries. (2) Additional time is saved because it is not necessary to fill in the blanks on the format sheet; merely write the Marine's name on the tape and attach it to the format sheet. The only optimization technique used in the program was to place those subroutines called most frequently at the top of the program listing.

The acronyms used in this appendix are:

CON	conduct
DI	drill instructor

DSZ	decrement and skip on zero
EST	essential subjects test
GMP	general military proficiency
MSG	Marine security guard
NC	not considered
PFT	physical fitness test
PRO	proficiency
TIG	time in grade
TIS	time in service

* *

Composite Score Format

Line		Rating
1	Rifle marksmanship score: ______________	______
2	PFT: _______ minus _______ = (+)(-) ___________ (score, minimum, difference)	______
3	Essential subjects: (number passed = ___)	______
4	Subtotal	______
5	GMP score (line 4 divided by ____)	______
6	GMP score (from line 5) ______ X 100	______
7	Average Duty Proficiency ______ X 100	______
8	Average Conduct ______ X 100	______
9	Time in Grade (months) ______ X 5	______
10	Time in Service (months) ______ X 2	______
11	DI/Recruiter/MSG Bonus ______ X 1	______
12	Self-Education Bonus ______ X 10	______
13	Composite Score (sum of lines 6 through 12)	______

* *

Instructions for Using the TI-59 Composite Score Calculation Program

Step	Instruction	Input	Press Key(s)	Output
1.	Repartition	2	OP 17	799.19
2.	Read sides 1, 2, 3 & 4 of the mag cards			
3.	Initialize		E"	2
4.	See Note 1			
5.	Enter rifle score	xxx	A"	rifle rating
6.a	Enter Marine's age	xx	B"	min acceptable score
b.	Enter PFT score	xxx	C"	PFT rating
7.	Enter EST's passed	x	D"	EST rating
8.	PRO marks: See Note 2	x.x	A	same as input
9.	CON marks: See Note 3	x.x	B	same as input
10.	Enter TIG	months	C	TIG rating
11.	Enter TIS	months	D	TIS rating
12.a.	Enter DI/Recruiter/ MSG bonus	See Note 4	E	same as input
b.	Enter Self-Education bonus	See Note 5	R/S	Composite Score

Note 1.

If NC is applicable for line 1, 2, and/or 3 on the Composite Score Format, skip program instruction steps 5, 6, and/or 7 respectively. The criterion for NC is defined in the Promotion Manual for each case. Should step 5, 6, or 7 be skipped, the zero in the next to the last group of numbers on the printout means NC. The program will compute the correct average.

Note 2.

Enter each PRO mark applicable as directed in the Promotion Manual, and press A following the entry of each mark. The calculator program will compute the average of all marks entered.

Note 3.

Enter each CON mark applicable, and press B following the entry of each mark.

Note 4.

If no bonus is applicable, enter zero (0) and press E. If a bonus is applicable, enter the number of points authorized by the Promotion Manual and press E.

Note 5.

If the Marine is entitled to self-education bonus points, enter the number authorized and press R/S.

Note 6.

It is recommended that the program instruction steps be performed in numerical sequence so that the printout data can be easily related to the lines on the Composite Score Format. Step 3 MUST be performed before computing each Marine's score. Step 12 must be performed last.

Note 7.

A description of the printout for a typical case is provided in the following example. The vertical spacing of numbers in the example corresponds to that on an actual printout.

```
200.    rifle marksmanship score
 4.4    composite score rating for that rifle score

 18.    Marine's age
258.    Marine's score on the PFT
  5.    composite score rating for that age and score

  9.    number of essential subjects passed
  5.    composite score rating for passing that many EST's

 4.1
 4.5    PRO marks
 4.9

 4.3
 4.5    CON marks
 4.7
```

17.	months TIG
85.	composite score rating for that much TIG
36.	months TIS
72.	composite score rating for that much TIS
0.	DI/Recruiter/MSG bonus points
1.	self-education bonus points
10.	composite score rating for that much self-education
4.5	composite score rating for the rifle score
5.	composite score rating for the Marine's PFT score
5.	composite score rating for the EST's passed
480.	(4.5 + 5 + 5) ÷ 3 X 100 = GMP rating
450.	average PRO mark X 100
450.	average CON mark X 100
85.	months TIG X 5
72.	months TIS X 2
0.	DI/Recruiter/MSG bonus points
10.	self education bonus points
1547.	total composite score.

* *

Data Register Usage in the Program

Register	Usage
00	used in converting the rifle score to a rating
01	composite score rating for the rifle score
02	composite score rating for the PFT score
03	composite score rating for the EST's passed
04	DSZ register - advances the tape before Step 9
05	summation register for number of GMP factors
06	summation register for PRO marks
07	summation register for CON marks
08	not used
09	composite score rating for TIG
10	composite score rating for TIS
11	minimum acceptable PFT score for Marine's age
12	PFT score less register 11
13	last PRO mark entered
14	last CON mark entered
15	number of PRO marks entered
16	number of CON marks entered
17	DI/Recruiter/MSG bonus points
18	composite score rating for self-education points
19	total composite score

Labels Used in the Program

Numerical Location in the Program Listing	Label	TI-59 code for that Label	Purpose
001	$X^{.5}$	34	converts PFT score to composite score rating
009	1/X	35	converts rifle score to composite score rating
021	A	11	used to enter each PRO mark
034	B	12	used to enter each CON mark
050	)	54	averages all PRO marks entered
067	LNX	23	averages all CON marks entered
084	(	53	prints EST rating
091	ADV	98	advances tape before printing first CON mark
096	E"	10	initialization step
105	A"	16	used to enter rifle score
226	Y^X	45	prints rifle rating
232	B"	17	used to enter Marine's age
259	X^2	33	provides exit from routine that determines the minimum acceptable PFT score for the Marine's age
264	C"	18	used to enter the PFT score
566	EE	52	prints the PFT rating
572	D"	19	used to enter EST's passed
659	C	13	used to enter months TIG
670	D	14	used to enter months TIS
681	E	15	enters bonus and computes total composite score

000	76	LBL
001	34	ΓX
002	43	RCL
003	12	12
004	22	INV
005	77	GE
006	52	EE
007	92	RTN
008	76	LBL
009	35	1/X
010	05	5
011	94	+/-
012	44	SUM
013	00	00
014	43	RCL
015	00	00
016	22	INV
017	77	GE
018	45	YX
019	92	RTN
020	76	LBL
021	11	A
022	99	PRT
023	42	STO
024	13	13
025	44	SUM
026	06	06
027	01	1
028	44	SUM
029	15	15
030	43	RCL
031	13	13
032	91	R/S
033	76	LBL
034	12	B
035	97	DSZ
036	04	04
037	98	ADV
038	99	PRT
039	42	STO
040	14	14
041	44	SUM
042	07	07
043	01	1
044	44	SUM
045	16	16
046	43	RCL
047	14	14
048	91	R/S
049	76	LBL
050	54	)
051	43	RCL
052	06	06
053	65	×
054	01	1
055	00	0
056	00	0
057	95	=
058	55	÷
059	43	RCL
060	15	15
061	95	=
062	44	SUM
063	19	19
064	99	PRT
065	92	RTN
066	76	LBL
067	23	LNX
068	43	RCL
069	07	07
070	65	×
071	01	1
072	00	0
073	00	0
074	95	=
075	55	÷
076	43	RCL
077	16	16
078	95	=
079	44	SUM
080	19	19
081	99	PRT
082	92	RTN
083	76	LBL
084	53	(
085	43	RCL
086	03	03
087	99	PRT
088	98	ADV
089	91	R/S
090	76	LBL
091	98	ADV
092	98	ADV
093	61	GTO
094	12	B
095	76	LBL

```
096  10 E'
097  47 CMS
098  02  2
099  42 STO
100  04  04
101  98 ADV
102  98 ADV
103  91 R/S
104  76 LBL
105  16 A'
106  98 ADV
107  99 PRT
108  32 X:T
109  02  2
110  03  3
111  04  4
112  42 STO
113  00  00
114  05  5
115  42 STO
116  01  01
117  01  1
118  44 SUM
119  05  05
120  71 SBR
121  35 1/X
122  04  4
123  93  .
124  09  9
125  42 STO
126  01  01
127  71 SBR
128  35 1/X
129  04  4
130  93  .
131  08  8
132  42 STO
133  01  01
134  71 SBR
135  35 1/X
136  04  4
137  93  .
138  07  7
139  42 STO
140  01  01
141  71 SBR
142  35 1/X
143  04  4
144  93  .
145  06  6
146  42 STO
147  01  01
148  71 SBR
149  35 1/X
150  04  4
151  93  .
152  05  5
153  42 STO
154  01  01
155  71 SBR
156  35 1/X
157  04  4
158  93  .
159  04  4
160  42 STO
161  01  01
162  71 SBR
163  35 1/X
164  04  4
165  93  .
166  02  2
167  42 STO
168  01  01
169  71 SBR
170  35 1/X
171  04  4
172  42 STO
173  01  01
174  71 SBR
175  35 1/X
176  03  3
177  93  .
178  08  8
179  42 STO
180  01  01
181  71 SBR
182  35 1/X
183  03  3
184  93  .
185  05  5
186  42 STO
187  01  01
188  71 SBR
189  35 1/X
190  03  3
191  93  .
```

192	01	1
193	42	STO
194	01	01
195	71	SBR
196	35	1/X
197	02	2
198	93	.
199	06	6
200	42	STO
201	01	01
202	71	SBR
203	35	1/X
204	02	2
205	42	STO
206	01	01
207	71	SBR
208	35	1/X
209	01	1
210	93	.
211	03	3
212	42	STO
213	01	01
214	71	SBR
215	35	1/X
216	93	.
217	05	5
218	42	STO
219	01	01
220	71	SBR
221	35	1/X
222	00	0
223	42	STO
224	01	01
225	76	LBL
226	45	YX
227	43	RCL
228	01	01
229	99	PRT
230	91	R/S
231	76	LBL
232	17	B'
233	98	ADV
234	99	PRT
235	32	X:T
236	07	7
237	08	8
238	42	STO
239	11	11
240	03	3
241	09	9
242	22	INV
243	77	GE
244	33	X²
245	08	8
246	04	4
247	42	STO
248	11	11
249	02	2
250	06	6
251	22	INV
252	77	GE
253	33	X²
254	09	9
255	05	5
256	42	STO
257	11	11
258	76	LBL
259	33	X²
260	43	RCL
261	11	11
262	91	R/S
263	76	LBL
264	18	C'
265	99	PRT
266	75	-
267	43	RCL
268	11	11
269	95	=
270	32	X:T
271	01	1
272	04	4
273	09	9
274	42	STO
275	12	12
276	05	5
277	42	STO
278	02	02
279	01	1
280	44	SUM
281	05	05
282	71	SBR
283	34	ΓX
284	01	1
285	03	3
286	09	9
287	42	STO

```
288  12  12
289  04  4
290  93  .
291  09  9
292  42 STO
293  02  02
294  71 SBR
295  34 √X
296  01  1
297  02  2
298  09  9
299  42 STO
300  12  12
301  04  4
302  93  .
303  08  8
304  42 STO
305  02  02
306  71 SBR
307  34 √X
308  01  1
309  01  1
310  09  9
311  42 STO
312  12  12
313  04  4
314  93  .
315  07  7
316  42 STO
317  02  02
318  71 SBR
319  34 √X
320  01  1
321  00  0
322  09  9
323  42 STO
324  12  12
325  04  4
326  93  .
327  06  6
328  42 STO
329  02  02
330  71 SBR
331  34 √X
332  08  8
333  09  9
334  42 STO
335  12  12
336  04  4
337  93  .
338  05  5
339  42 STO
340  02  02
341  71 SBR
342  34 √X
343  06  6
344  09  9
345  42 STO
346  12  12
347  04  4
348  93  .
349  01  1
350  42 STO
351  02  02
352  71 SBR
353  34 √X
354  03  3
355  09  9
356  42 STO
357  12  12
358  04  4
359  42 STO
360  02  02
361  71 SBR
362  34 √X
363  02  2
364  09  9
365  42 STO
366  12  12
367  03  3
368  93  .
369  05  5
370  42 STO
371  02  02
372  71 SBR
373  34 √X
374  01  1
375  09  9
376  42 STO
377  12  12
378  03  3
379  93  .
380  03  3
381  42 STO
382  02  02
383  71 SBR
```

384	34	√X
385	09	9
386	42	STO
387	12	12
388	03	3
389	93	.
390	01	1
391	42	STO
392	02	02
393	71	SBR
394	34	√X
395	01	1
396	94	+/-
397	42	STO
398	12	12
399	03	3
400	42	STO
401	02	02
402	71	SBR
403	34	√X
404	04	4
405	94	+/-
406	42	STO
407	12	12
408	02	2
409	93	.
410	05	5
411	42	STO
412	02	02
413	71	SBR
414	34	√X
415	06	6
416	94	+/-
417	42	STO
418	12	12
419	02	2
420	93	.
421	04	4
422	42	STO
423	02	02
424	71	SBR
425	34	√X
426	07	7
427	94	+/-
428	42	STO
429	12	12
430	02	2
431	93	.
432	03	3
433	42	STO
434	02	02
435	71	SBR
436	34	√X
437	08	8
438	94	+/-
439	42	STO
440	12	12
441	02	2
442	93	.
443	01	1
444	42	STO
445	02	02
446	71	SBR
447	34	√X
448	09	9
449	94	+/-
450	42	STO
451	12	12
452	01	1
453	93	.
454	09	9
455	42	STO
456	02	02
457	71	SBR
458	34	√X
459	01	1
460	00	0
461	94	+/-
462	42	STO
463	12	12
464	01	1
465	93	.
466	07	7
467	42	STO
468	02	02
469	71	SBR
470	34	√X
471	01	1
472	01	1
473	94	+/-
474	42	STO
475	12	12
476	01	1
477	93	.
478	05	5
479	42	STO

```
480  02  02
481  71  SBR
482  34  √X
483  01   1
484  02   2
485  94  +/-
486  42  STO
487  12   12
488  01   1
489  93   .
490  03   3
491  42  STO
492  02   02
493  71  SBR
494  34  √X
495  01   1
496  03   3
497  94  +/-
498  42  STO
499  12   12
500  01   1
501  93   .
502  01   1
503  42  STO
504  02   02
505  71  SBR
506  34  √X
507  01   1
508  04   4
509  94  +/-
510  42  STO
511  12   12
512  93   .
513  09   9
514  42  STO
515  02   02
516  71  SBR
517  34  √X
518  01   1
519  05   5
520  94  +/-
521  42  STO
522  12   12
523  93   .
524  07   7
525  42  STO
526  02   02
527  71  SBR
528  34  √X
529  01   1
530  06   6
531  94  +/-
532  42  STO
533  12   12
534  93   .
535  05   5
536  42  STO
537  02   02
538  71  SBR
539  34  √X
540  01   1
541  07   7
542  94  +/-
543  42  STO
544  12   12
545  93   .
546  03   3
547  42  STO
548  02   02
549  71  SBR
550  34  √X
551  01   1
552  08   8
553  94  +/-
554  42  STO
555  12   12
556  93   .
557  01   1
558  42  STO
559  02   02
560  71  SBR
561  34  √X
562  00   0
563  42  STO
564  02   02
565  76  LBL
566  52  EE
567  43  RCL
568  02   02
569  99  PRT
570  91  R/S
571  76  LBL
572  19  D'
573  98  ADV
574  99  PRT
575  32  X:T
```

```
576  05   5
577  42  STO
578  03   03
579  01   1
580  44  SUM
581  05   05
582  08   8
583  22  INV
584  77   GE
585  53   (
586  04   4
587  93   .
588  08   8
589  42  STO
590  03   03
591  07   7
592  22  INV
593  77   GE
594  53   (
595  04   4
596  93   .
597  07   7
598  42  STO
599  03   03
600  06   6
601  22  INV
602  77   GE
603  53   (
604  04   4
605  93   .
606  04   4
607  42  STO
608  03   03
609  05   5
610  22  INV
611  77   GE
612  53   (
613  03   3
614  93   .
615  07   7
616  42  STO
617  03   03
618  04   4
619  22  INV
620  77   GE
621  53   (
622  03   3
623  42  STO
624  03   03
625  03   3
626  22  INV
627  77   GE
628  53   (
629  02   2
630  93   .
631  03   3
632  42  STO
633  03   03
634  02   2
635  22  INV
636  77   GE
637  53   (
638  01   1
639  93   .
640  06   6
641  42  STO
642  03   03
643  01   1
644  22  INV
645  77   GE
646  53   (
647  93   .
648  08   8
649  42  STO
650  03   03
651  00   0
652  22  INV
653  77   GE
654  53   (
655  00   0
656  42  STO
657  03   03
658  76  LBL
659  13   C
660  98  ADV
661  99  PRT
662  65   ×
663  05   5
664  95   =
665  42  STO
666  09   09
667  99  PRT
668  91  R/S
669  76  LBL
670  14   D
671  98  ADV
```

```
672  99 PRT
673  65  ×
674  02  2
675  95  =
676  42 STO
677  10  10
678  99 PRT
679  91 R/S
680  76 LBL
681  15  E
682  98 ADV
683  99 PRT
684  42 STO
685  17  17
686  91 R/S
687  98 ADV
688  99 PRT
689  65  ×
690  01  1
691  00  0
692  95  =
693  99 PRT
694  42 STO
695  18  18
696  98 ADV
697  43 RCL
698  01  01
699  99 PRT
700  85  +
701  43 RCL
702  02  02
703  99 PRT
704  85  +
705  43 RCL
706  03  03
707  99 PRT
708  95  =
709  55  ÷
710  43 RCL
711  05  05
712  65  ×
713  01  1
714  00  0
715  00  0
716  95  =
717  98 ADV
718  99 PRT
719  44 SUM
720  19  19
721  71 SBR
722  54  )
723  71 SBR
724  23 LNX
725  43 RCL
726  19  19
727  85  +
728  43 RCL
729  09  09
730  99 PRT
731  85  +
732  43 RCL
733  10  10
734  99 PRT
735  85  +
736  43 RCL
737  17  17
738  99 PRT
739  85  +
740  43 RCL
741  18  18
742  99 PRT
743  95  =
744  42 STO
745  19  19
746  99 PRT
747  91 R/S
```

APPENDIX D

A CALCULATOR PROGRAM WHICH COMPUTES THE PHYSICAL FITNESS TEST SCORE

Listed below are the instructions for operating the TI-59 program which takes raw scores from the USMC male Physical Fitness Test (PFT) events and outputs the standard score for each event and a total overall score for the PFT.

Step	Instruction	Input	Press Key	Output
1.	Read magnetic card sides 1 and 4			See note 1
2.	Enter number of pulls ups	xx < 21	A	See note 2
3.	Enter number of sit ups	xx < 81	B	See note 3
4.	Enter run time in min. & sec.	xx.xx > 12	C	See note 4
5.	Compute total		D	See note 5

Note 1.

This program can be run with or without a printer for the TI-59. If a printer is used, labels as described in the following notes will be printed along with the scores.

Note 2.

If the Marine achieves more than twenty pull ups, enter the number 20. This is because the program generates an

error message if a number greater than 20 is entered and key A is pressed. For purposes of illustration, it could be assumed that the Marine whose score is being calculated had performed 78 sit ups and the calculator operator had correctly entered 78 but had erroneously pressed A instead of B. In that case the printer tape will look like this:

78
PULLUP ENTRY INVALID

In addition, the display will flash 9.9999999 99, which represents 9.9999999 times 10 to the 99th power, the largest number the TI-59 can generate. If a printer is not used, 9.9999999 99 will be flashed to indicate an invalid entry has occurred. In either case, simply enter the correct number and press the correct action key.

If, for example, 15 is entered, the output on the printer tape will look like this:

15
75 PULL

Regardless of whether the printer is or is not used, the TI-59 will stop with 75 in the display after 15 is entered and A is pressed.

Note 3.

If the Marine achieves more than eighty sit ups, enter the number 80. Otherwise, an error message is generated. If a number greater than 80, such as 81, is entered and B pressed, the tape will look like this:

81
SIT UP ENTRY INVALID

The TI-59 will flash 9.9999999 99 to call attention to the invalid entry regardless of whether or not a printer is being used.

If, for example, 78 is entered and B pressed, the output on the printer tape will look like this:

78
96 SIT

With or without a printer, the TI-59 will stop with 96 in the display.

Note 4.

For the three-mile run, the number to be entered into the calculator is the minutes followed by a decimal followed by the seconds. For twenty-two minutes and fifty seconds the entry will be 22.50. Since the PFT order directs that the timer only report the time in ten second intervals, 22.5 could be entered instead of 22.50. Do not enter a number such as 22.55. The printer tape for such a time will look like this:

22.5
71 RUN

The calculator displays 71 after the computation to indicate the standard score for that event.

If the calculator operator fails to press one of the number keys hard enough and doesn't notice that, for example, 2.5 instead of 22.5 is in the display prior to C being

pressed, the program will generate the following message if a printer is attached.

2.5
RUN ENTRY INVALID

As in the previous cases, 9.9999999 99 will be flashed in the display to draw attention to the error condition.

Note 5.

After pressing D to sum the three standard scores, the TI-59 display will show the total. For the three valid entries discussed in the previous notes, the total would be 242. The printer tape for the whole sequence will look like this:

```
  15
  75   PULL
  78
  96   SIT
22.5
  71   RUN
 242   TOTL
```

Note 6.

The steps may be performed in any order except that, of course, step 5 must be last. After step 5, the printer advances one space, and entries for the next Marine can be made.

* *

Contents of the Storage Registers in the TI-59 PFT Score Calculation Program

Register Number	Contents
0	not used
1	pull up entry

Contents of the Storage Registers in the
TI-59 PFT Score Calculation Program - Concluded

Register Number	Contents
2	sit up entry
3	run entry
4	pull up standard score
5	sit up standard score
6	run standard score
7	total score
8	not used
9	not used
10	not used
11	34.3
12	100
13	not used
14	34.1
15	not used
16	code to generate PULLU
17	code to generate SIT U
18	code to generate P ENT
19	code to generate RU
20	code to generate N ENT
21	code to generate RY IN
22	code to generate VALID
23	code to generate PULL
24	code to generate SIT
25	code to generate RUN
26	code to generate TOTL

* *

The program listing for the TI-59 PFT Score Calculation Program is contained in the remaining pages of this appendix.

```
000  76 LBL
001  11  A
002  42 STO
003  01  01
004  99 PRT
005  02  2
006  01  1
007  32 X:T
008  43 RCL
009  01  01
010  77  GE
011  42 STO
012  65  ×
013  05  5
014  95  =
015  42 STO
016  04  04
017  43 RCL
018  23  23
019  69 OP
020  04  04
021  43 RCL
022  04  04
023  69 OP
024  06  06
025  91 R/S
026  76 LBL
027  12  B
028  42 STO
029  02  02
030  42 STO
031  05  05
032  99 PRT
033  08  8
034  01  1
035  32 X:T
036  43 RCL
037  02  02
038  77  GE
039  43 RCL
040  06  6
041  01  1
042  32 X:T
043  43 RCL
044  02  02
045  77  GE
046  17 B'
047  61 GTO
048  99 PRT
049  76 LBL
050  17 B'
051  75  -
052  06  6
053  00  0
054  95  =
055  44 SUM
056  05  05
057  76 LBL
058  99 PRT
059  43 RCL
060  24  24
061  69 OP
062  04  04
063  43 RCL
064  05  05
065  69 OP
066  06  06
067  91 R/S
068  76 LBL
069  13  C
070  42 STO
071  03  03
072  99 PRT
073  32 X:T
074  01  1
075  02  2
076  77  GE
077  44 SUM
078  01  1
079  08  8
080  77  GE
081  18 C'
082  43 RCL
083  14  14
084  22 INV
085  77  GE
086  58 FIX
087  43 RCL
088  03  03
089  88 DMS
090  65  ×
091  06  6
092  95  =
093  94 +/-
094  85  +
095  02  2
096  00  0
097  08  8
```

098	95	=
099	42	STO
100	06	06
101	76	LBL
102	90	LST
103	43	RCL
104	25	25
105	69	OP
106	04	04
107	43	RCL
108	06	06
109	69	OP
110	06	06
111	91	R/S
112	76	LBL
113	18	C'
114	43	RCL
115	12	12
116	42	STO
117	06	06
118	61	GTO
119	90	LST
120	76	LBL
121	58	FIX
122	03	3
123	06	6
124	22	INV
125	77	GE
126	97	DSZ
127	03	3
128	05	5
129	22	INV
130	77	GE
131	98	ADV
132	43	RCL
133	11	11
134	22	INV
135	77	GE
136	87	IFF
137	03	3
138	42	STO
139	06	06
140	61	GTO
141	90	LST
142	76	LBL
143	97	DSZ
144	00	0
145	42	STO
146	06	06
147	61	GTO
148	90	LST
149	76	LBL
150	98	ADV
151	01	1
152	42	STO
153	06	06
154	61	GTO
155	90	LST
156	76	LBL
157	87	IFF
158	02	2
159	42	STO
160	06	06
161	61	GTO
162	90	LST
163	76	LBL
164	14	D
165	43	RCL
166	04	04
167	85	+
168	43	RCL
169	05	05
170	85	+
171	43	RCL
172	06	06
173	95	=
174	42	STO
175	07	07
176	43	RCL
177	26	26
178	69	OP
179	04	04
180	43	RCL
181	07	07
182	69	OP
183	06	06
184	98	ADV
185	91	R/S
186	76	LBL
187	42	STO
188	43	RCL
189	16	16
190	69	OP
191	01	01
192	43	RCL
193	18	18
194	69	OP
195	02	02

196	61	GTO
197	76	LBL
198	76	LBL
199	43	RCL
200	43	RCL
201	17	17
202	69	OP
203	01	01
204	43	RCL
205	18	18
206	69	OP
207	02	02
208	61	GTO
209	76	LBL
210	76	LBL
211	44	SUM
212	43	RCL
213	19	19
214	69	OP
215	01	01
216	43	RCL
217	20	20
218	69	OP
219	02	02
220	76	LBL
221	76	LBL
222	43	RCL
223	21	21
224	69	OP
225	03	03
226	43	RCL
227	22	22
228	69	OP
229	04	04
230	69	OP
231	05	05
232	01	1
233	55	÷
234	00	0
235	95	=
236	98	ADV
237	91	R/S

LIST OF REFERENCES

1. Kruse, H. R., and Burkett, H. A., Investigation of Card Programmable and Chip Programmable Pocket Calculators and Calculator Systems for Use at Naval Postgraduate School and in the Naval Establishment, M.S. Thesis, Naval Postgraduate School, Monterey, CA, March 1977.

2. Olympic Sales Co., "Save On Calculators," The Wall Street Journal (Western Edition), p. 2, 26 January 1981.

3. Siegel, W. M., Computerization of Tactical Aircraft Performance Data for Fleet Application, M.S. Thesis, Naval Postgraduate School, Monterey, CA, June 1978.

4. Koger, G. L., The Development and Implementation of Algorithms for an A-7E Performance Calculator, M.S. Thesis, Naval Postgraduate School, Monterey, CA, September 1978.

5. Restivo, J. D., Computerization of Aircraft Naval Air Training and Operating Procedures Standardization (NATOPS) Flight Performance Charts, M.S. Thesis, Naval Postgraduate School, Monterey, CA, June 1978.

6. Naval Air Systems Command, Requisition Number N0019-77-RQ-76B79, 23 August 1977.

7. McDonald Douglas Corporation, AV-8A/TAV-8A V/STOL-REST Flight Calculator, p. 2, 1978.

8. U. S. Army Field Artillery School, Hand Held Calculator Cannon Program Packet Guidance Package, p. 1, May 1978.

9. U. S. Army Training and Doctrine Activity Combined Arms Test Activity Report 00129, Hand-Held Programable Calculator Evaluation, September 1979.

10. Stratman, Henry W., and others, "The Hand-held Calculator: Meeting Today's Needs Today!", Field Artillery Journal, pp. 8-13, January-February 1980.

11. Naval Air Systems Command Letter AIR-5286/MKM to Sikorsky Aircraft Division, United Technologies Corporation, Subject: Contract N0019-78-C-0146, Model CH-53E Heli-

copter; Engineering Change Proposal (ECP) to Replace the MIL-C-6092A Balance Computer With an Electronic Calculator for Weight, Balance, and Performance Calculations, p. 1, 1 May 1980.

12. Beech Aircraft Corporation, Part Number: 98-38754, Operator's Manual for the Beechcraft Flight Planning Computer, pp. 6-8, September 1980.

13. Silitch, M. F., "New Products: Computing Fuel Savings," AOPA Pilot, p. 30, September 1980.

14. U. S. Army Training and Doctrine Activity Combined Arms Test Activity Report CEP 002, Hand-Held Programmable Calculator Mortar Data Module Firing Program Evaluation, May 1980.

15. McDonald Douglas Corporation Letter to Naval Air Systems Command, Attention: AIR-5103J, Subject: Harrier Electronic VSTOL/REST Performance Calculator, 2 June 1977.

BIBLIOGRAPHY

"Custom HP-41C's Take Off," The Hewlett-Packard Personal Calculator DIGEST, v. 7, pp. 2-5, 1980.

1st Marine Aircraft Wing NATOPS Supervisor Letter to Major J. L. Reeve, Subject: Hand-Held Calculators, 22 December 1980.

4th Marine Aircraft Wing NATOPS Officer Letter 3:MAS:reb over 3510 to Major J. L. Reeve, Subject: Proposed Use of Hand-Held Calculators by 4th MAW Aircrews, 29 September 1980.

Marine Corps Order P1400.29B, Marine Corps Promotion Manual, 2 March 1977.

Marine Corps Order 6100.3H, Physical Fitness, 23 October 1980.

NAVAIR 01-85ADA-1, NATOPS Flight Manual, Navy Model A-6A,B, C/KA-6D/A-6E Aircraft, 1 August 1974.

Personal Programming, Texas Instruments Incorporated, 1977.

2nd Marine Aircraft Wing NATOPS Officer Letter to Major J. L. Reeve, Subject: Hand-Held Computer Survey, 27 October 1980.

3rd Marine Aircraft Wing Letter 25:FEL:dmw over 3510 to Major J. L. Reeve, Subject: Computerization of NATOPS Performance Data Charts, 10 September 1980.

TI Programmable 58/59 Aviation, Texas Instruments Incorporated, 1977.

Weir, M. D., An Introduction to the TI-59 Programmable Calculator, Naval Postgraduate School, 1979.

Weir, M. D., Calculator Clout: Methods of Programmable Calculators, Prentice-Hall Inc., 1981.

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